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EDITORIAL

The unavoidable delay in the issuing of this, the last copy of the *Journal* to appear in the present format, enables us to commit the apparent anachronism of saluting the great achievement of Russian engineers in launching their "cosmic rocket" on 2 January, 1959.

It is, of course, not only a great engineering achievement: the experiment will yield valuable scientific results; its political implications are already being discussed elsewhere. However, it is also a historical event of major importance. If the launching of Sputnik I was significant because it represented the first artificial Moon to be established by man, how much more noteworthy is the establishment of an artificial planet (even if only an asteroid). At last, it has been demonstrated in practice that it is possible to attain escape velocity.

The passage of the rocket close to the Moon might have been considered a lucky fluke were it not for the evidence of the three Sputniks. Instead it indicates that the Russian rockets have a guidance system of astonishingly high accuracy, much greater than might have been expected at this stage of the art. With the inevitable improvements that will result from operational experience we may confidently expect that before long it will be possible to have probes in orbit around the Moon, Mars and Venus.

Both Russia and the United States have plans for manned rocket flights during 1959—although the reports of Russian plans appearing in the press are no doubt exaggerated as far as timetables are concerned. We shall await eagerly the reports on all these activities which we expect to be given at the Tenth International Astronautical Congress to be held in London in September.

As yet these activities are confined to Russia and America, though it seems likely that China will soon enter the space race. Britain remains a spectator —or almost a spectator, for we must not forget the valuable observational and computational work carried out at the Royal Aircraft Establishment and elsewhere. A committee charged with advising the Government as to what more active part Britain might take in space research has been deliberating for some months, but this is a very leisurely procedure and no substitute for action. At this rate, by the time approval has been given for the construction of a British satellite, U.S.A. and U.S.S.R. will be firing planetary probes; by the time we have launched our satellite, a Russian expedition will be established on the Moon.

SOME CONSEQUENCES OF A THEORY OF THE RADIATION BELT*

By Professor S. F. Singer, Fellow†

SUMMARY

A theory has been developed[1] to account for the "radiation belt" reported by Explorer and Sputnik satellites. This theory gives the origin of the radiation, its nature and energy, and its distribution around the Earth with latitude and with altitude. This note summarizes the *results* of the theory and investigates its consequences for studies of the outer atmosphere of the Earth, the planets and Moon; particular attention is paid to space medical implications and means of protection against the radiation. The most promising counter-measure appears to be "sweeping-out" of the radiation. Finally, some novel experiments to test the trapping properties of the Earth's magnetic field are suggested.

1. Summary of Theory

Over the past few years we have studied the "trapping" and "storing" of radiation by the Earth's magnetic field, mainly in connection with a new theory of magnetic storms and aurorae.[2] The magnetic field can be shown to be a good "container" for *charged* particles of not too high energy; *i.e.*, once introduced, a charged particle will spiral around a line of force and remain in a certain region for a long time (uncharged particles, such as neutrons, and electromagnetic radiation cannot be trapped). The theory gives "life-times" ranging to tens of years at high altitudes. Therefore, a small injection rate can give very high intensities.‡

The next job is to look for some adequate injection mechanism. The only *known* method we have found so far which shows promise is the following.[1] Primary cosmic rays smash into the Earth's atmosphere in the vicinity of 20–25 km. (70,000 ft.) and disintegrate atmospheric nuclei. Neutrons are released with energies up to several hundred MeV., many of which travel upwards (and are therefore called cosmic ray "albedo").

Being uncharged the neutrons travel along straight lines, right through the Earth's magnetic field, out into space. But free neutrons are radioactive. A minute fraction of them change into protons while travelling through the field (about 10^{-13} per cm., or about one in a million in one hundred miles). These protons immediately spiral around the lines of force; a fraction are lost immediately as they get back too deep into the atmosphere, but the rest are trapped. A typical injection rate is 10^{-13}/cm.^{3}-sec., *i.e.*, one particle is injected into a given cm.^{3} of space every 300,000 years. But the "lifetime" is so long that the particle concentration builds up to 10^{-4} per cm.^{3} (3 per ft.^{3}) at 1,000 km. (600 miles). (*See Note* 1 *at end.*)

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‡ The situation is analogous to a water tank which has a very tiny leak; then a small injection rate can build up a high level.

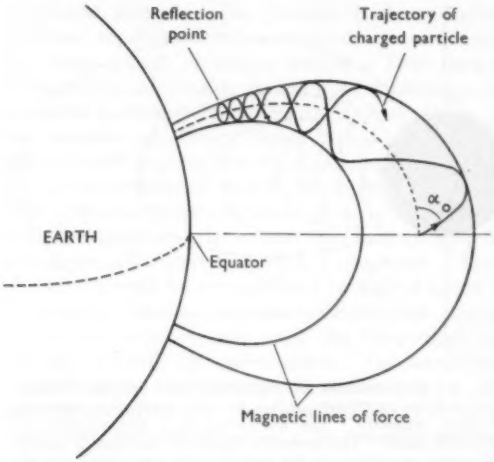

FIG. 1. Reflection and trapping of a charged particle by the Earth's magnetic field. The particle's velocity makes an angle α_0 to the magnetic line of force in the equatorial plane. With a smaller value of α_0 the particle will approach closer to the Earth's surface. With $\alpha_0 = 90°$, the particle remains in the equatorial plane.

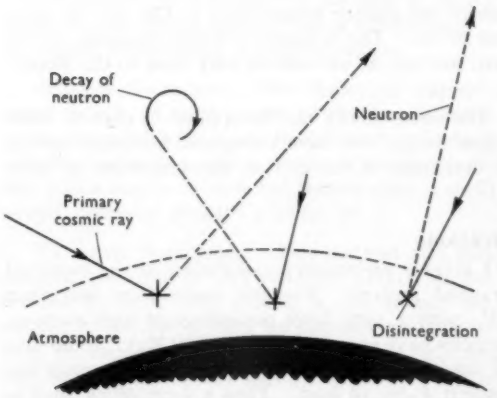

FIG. 2. Injection of particles into the magnetic "trap." Primary cosmic rays release energetic neutrons in nuclear disintegrations in the dense lower atmosphere. Some of the upward travelling albedo neutrons decay, giving their energy to the resulting proton.

The lifetime is inversely related to atmospheric density. Since the latter decreases with altitude, the lifetime and therefore intensity of the radiation increase with altitude. A maximum is reached at the equator at about $1\frac{1}{2}$ Earth radii (6,000 miles), beyond which the intensity drops. The radiation belt ends gradually, probably near 10 Earth radii where the interplanetary magnetic field is believed to take over. At higher latitudes the radiation belt is much thinner, and at the poles it is absent. These theoretical predictions[1] can be checked experimentally. The "Moon-shots" should give an excellent opportunity for such measurements. (*See Note 2 at end.*)

2. Applications to Cosmic Physics

Solar Neutrons. Since the cosmic ray albedo gives us adequate intensities we can set *upper limits* to other possible, but *unknown* mechanisms For example, the *time-averaged* flux of high energy neutrons from the Sun cannot greatly exceed 0·1/cm.^{2}-sec. If it did, then the radiation belt intensity would be higher and *would not fall off* beyond 6,000 miles.

Earth's Exosphere. One of the most exciting applications is to deduce the density, composition and temperature of the atmosphere above 400 km. (250 miles) from the altitude variation of the radiation belt intensity. The method is discussed in detail in Ref. 1. For example, using a realistic model of the exosphere we derive an increase of about 1 per cent. per mile near 400 miles. (*See Note* 3 *at end.*)

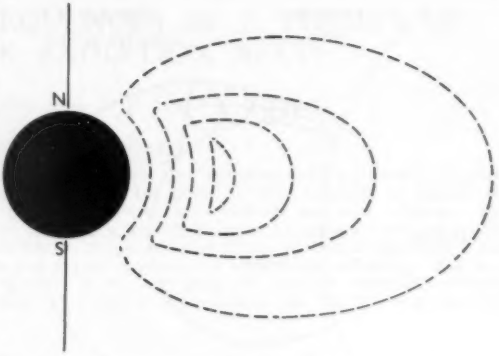

FIG. 3. Distribution of radiation belt around Earth, derived from the theory in Ref. 1. The lines give contours of equal intensity. The maximum is in the vicinity of 1·5 Earth radii. The intensity begins to increase at about 250 miles (according to the theory) and may reach out to ~10 Earth radii (40,000 miles) at the equator. Note that the regions around the poles are clear.

Lunar Magnetic Field and Atmosphere. We can predict a radiation belt around the Moon, *if* the Moon has a dipole field. Conversely, if on a lunar impact trajectory we find a radiation belt, we can deduce the strength of the field. From the detailed variation of intensity with altitude above the lunar surface, we can deduce the composition of the lunar atmosphere. For example, if the atmosphere consists of krypton and xenon, then on the daylight side (where the surface temperature is 135° C.) the scale height $H_0 = kT/\bar{\mu}Mg$ is about 20 km. The radiation intensity therefore would decrease by nearly 10 per cent. per mile as we come in very close to the Moon's surface.

Planetary Atmospheres. The same theory can be applied to planets, such as Mars and Venus. Since they are likely to have a magnetic field, our method should make it possible to determine it, as well as the properties of their atmospheres.

3. Space Medical Implications

Energy Spectrum. Ref. 1 gives a preliminary calculation of the expected energy spectrum of the trapped protons. Energies range from less than 5 MeV. to perhaps 400 MeV., with a very large percentage of high energies. About 50 per cent. of the particles have energies less than 100 MeV.; to remove them requires 1 cm. of lead shielding. To reduce the intensity to much less than 10 per cent. requires about 4 cm. of lead. Thus a 4-cm.-thick shell to shield a sphere of diameter 4 metres (12 ft.) would require over 10,000 lb. lead. In Ref. 1 we discuss the approximation introduced into the calculations; the exact theory (which is very difficult to calculate out) leads to less high-energy protons, but even 5,000 lb. of shielding may be impractical.

Health Hazards. The protons in the radiation belt are quite equivalent to those accelerated in a cyclotron. In addition to the very high flux they also have a high ionization density. Thus their effects will be very serious, particularly, of course, on complex molecules, such as living cells or genes, but even on long-chain molecules, such as rubber. At an altitude of 1,000 km. we calculate an energy density of $\sim 10^4$ eV./cm.^{3}, and therefore an energy flux of ~ 100 erg/cm.^{2}-sec.* Assuming a little shielding (equivalent to 4 mm. of lead we reduce the flux to about 60 per cent.; and spreading the ionization over a 60 cm. length of tissue gives an energy dissipation of 1 erg/g.-sec., or 0·01 roentgen/sec. In a year this amounts to 3×10^5 r. compared to the maximum allowable dose of 5 r. per year. The "maximum lifetime dose" of 100 r. would be accumulated in only 3 hours' exposure.*

Clearly, manned satellite spacestations operating in the radiation belt cannot be declared safe until the theoretical predictions are modified (or possibly refuted) by experiments. The situation could even be serious for escape from the Earth *through* the radiation belt. The theory, however, suggests that the regions around the poles are clear of this trapped radiation. Launching from very high latitudes may be essential for interplanetary operations.

4. Counter-Measures to the Radiation Belt

Avoidance. Operation of satellites below 250 miles or above 40,000 miles should give radiation levels corresponding only to the primary cosmic radiation. Its altitude dependence has been calculated earlier.[3] Interplanetary launchings may have to be carried out near the poles.

Shielding. As discussed in Section 3, heavy shields may be required which may be impractical for many applications. The author therefore wants to suggest three novel counter-measures:

Shadow Shielding. The theory of trapped particles shows[1] that they spiral mainly at right angles to the line of force and are therefore incident mainly perpendicular to the line of force. (In fact, the line of force defines the axis of a double-cone which is clear of incident particles.) Therefore a shielding *ring* which has to be oriented (rather than a shell) may be sufficient, giving a weight saving of perhaps a factor 10.

Magnetic Screening. This method also makes use of the fact that the incident radiation is very strongly peaked in the direction perpendicular to the line of force. By putting a coil around the spacestation with its axis parallel to the line of force we can create a small-scale dipole field which turns away the incident radiation. We can give some rough figures: to affect protons with momentum of 400 MeV./c. requires a magnetic moment of about 10^{10} gauss-cm.^{3} To create this moment for a 4 metre (12 ft.) vehicle takes about 10^6 ampere-turns. However, the power required is quite stupendous, 36 MW. for an aluminium coil of cross-section 10 cm. $\times$ 10 cm.

* See Note 1 at end.

"SPACE SWEEPER." Perhaps the most radical suggestion is to construct a satellite whose purpose is it to "sweep out" a channel in the radiation belt, *i.e.*, remove the protons by absorbing those which hit it. This scheme may work because the injection rate is so small.* It requires, however, one or more satellites of very large area. The cross-sectional area of the swept-out channel is quite large so that a reasonable number of "sweeper satellites" could reduce the radiation belt to tolerable limits. We will now give some approximate numbers to indicate how well the "space sweeper" would operate. As an example, we will let it operate in a circular equatorial orbit at an altitude of 1,000 km. If its cross-sectional area is A_s, then it absorbs

$$j_A A_s = A_s N \beta c 4\pi \cos \alpha_c \text{ particles (of velocity } \beta) \text{ per sec.} \quad .. \quad (1)$$

We are using our earlier[1] notation,† with j_A the differential flux. The cross-sectional area of the swept channel does *not* depend on A, and is given by

$$A_c = (R \cdot \Delta\lambda)\, \rho = R \frac{H_0}{2R} \cdot \frac{Mc^2\beta}{300B} \quad .. \quad .. \quad (2)$$

For example, at 1,000 km. altitude, using $H_0 = 200$ km., and $\beta \simeq 0{\cdot}2$, we get

$$A_c = 3 \times 10^{13} \text{ cm.}^2$$

The swept volume V is then given simply as

$$V = 2\pi R A_c; \quad \text{at 1,000 km., } V \simeq 10^{23} \text{ cm.}^3 \text{ for } \beta = 0{\cdot}2 \quad .. \quad (3)$$

We can now define an effective removal rate of particles Q' as

$$Q' = jA_s/V = A_s N (\beta c 4\pi \cos \alpha_c)/V \equiv C_6 A_s N \quad .. \quad .. \quad (4)$$

If we examine Eq. (8) of Ref. 1 we find that we can neglect Q and div j, so that

$$\partial N/\partial t + Q' = 0 \quad .. \quad .. \quad .. \quad .. \quad (5)$$

Substituting and solving for N, we get

$$N = N_0 \exp(-C_6 A_s t) \quad .. \quad .. \quad .. \quad (6)$$

Equation (6) breaks down when N becomes small, and the effect of Q is important.

A mean decay time T_D for the intensity of the radiation is given by

$$T_D = 1/C_6 A_s = \frac{1}{A_s} \cdot \frac{V}{\beta c 4\pi \cos \alpha_c} = \frac{1}{A_s} \cdot \frac{RH_0 Mc^2}{1200\, c\, B \cos \alpha_c} \quad .. \quad (7)$$

* In our analogy (footnote, p. 558) this amounts to making a large hole in the water tank, and waiting until the level goes down.

† β is velocity of particles in terms of light velocity c; α_c is the mean minimum pitch angle of the trapped protons and related to $\Delta\lambda$, the latitude angle interval occupied; R is distance from Earth's centre, ρ is radius of curvature (cm.) in magnetic field B (gauss); proton mass Mc^2 is in electron volts; the particle concentration (from Ref. 1) is given by $N(\beta) = C_4 \beta^{-\gamma+2}$ where $\gamma = 2{\cdot}6$ and $C_4 = 2{\cdot}2 \times 10^{-24}/d$, and where d is the atmospheric density.

Numerically, the sweep time $T_D \simeq (6 \times 10^{12})/A_s$; *i.e.*, about 1 year with sweeper satellite radius of about 5 metre, about one month if twelve sweeper satellites are used.

It is an interesting consequence of this theory that T_D is to a first approximation independent of the proton energy, but that the satellite sweeps up a larger *volume* of the higher energy particles in the same time.

5. A Trapped Particle Experiment

The "space sweeper" only works if our trapping theory is substantially correct, *i.e.*, if there are no other large leaks which we have overlooked.

In order to study just the storage properties of the Earth's magnetic field, we could suggest the following experiment. An accelerator carried aloft in a satellite could be used to inject electrons of appropriate energy, thereby increasing Q and produce an observable increase in J. This experiment would in effect measure Q and the mean lifetime T, and the time constant.

If we consider the injection of 2 MeV. electrons from an equatorial satellite orbiting at about 1,000 km., the volume V occupied by the particles after some time will be given by Equation (3) as before but with the radius of gyration appropriate to 2 MeV. electrons; numerically $V \sim 10^{21}$ cm.^{3}

If the mean output current of the electron accelerator is 500 microamp., *i.e.*, 3×10^{15} electrons per second, then the mean injection rate becomes $Q = 3 \times 10^{15}/10^{21} = 3 \times 10^{-6}$ electrons per cm.^{3} per second. From our previous discussion[1] we estimate that one-third of these remain trapped. Since the concentration of particles of the natural radiation belt is of the order of 10^{-5}/cm.^{3}, we can double the radiation intensity after about 10 seconds. The intensity will build up to a very much larger steady-state value, and decays away very slowly to its original value after the accelerator is turned off.

This artificial radiation belt could be swept out very easily since the range of 2 MeV. electrons is only a few mm. of aluminium.

Experiments of this type would add very much to our understanding of phenomena in the environment of the Earth.

6. Uses of the Radiation Belt Energy

The energy densities and fluxes are very high, as calculated below, but their utilization will tax our ingenuity.

We calculate the energy density (using notation of Ref. 1):

$$\bar{E} \simeq \int N(\beta) \cdot (\tfrac{1}{2}\beta^2 Mc^2) d\beta = \tfrac{1}{2} Mc^2 \int C_4 \beta^{4-\gamma} d\beta$$

$$= \frac{C_4 Mc^2}{10 - 2\gamma} \left[\beta_2^{5-\gamma} - \beta_1^{5-\gamma}\right]$$

Numerically, at 1,000 km., we get $\bar{E} \simeq 10^4$ eV./cm.^{3}; the energy flux is $\bar{E}\beta c$ or about 100 ergs/cm.^{2}/sec.

NOTES ADDED IN PROOF

1. These values were calculated using the *conventional* value for atmospheric density at 1000 km., *i.e.*, 10^{-19} g./cm^3. Recent work by the author on the density of the exosphere[4] gives a value of 10^{-17} g./cm^3. Hence the calculated radiation intensities must be reduced by about a factor 100.

2. Preliminary reports from the Pioneer rocket fired in October, 1958 indicate a maximum near this predicted value.

3. Using the new model of exosphere densities[4] we derive an intensity increase of a factor 3 per 100 km. (in the interval 500 to 900 km.) and 15 per cent. per 100 km. above 1200 km.

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RELATIVITY AND SPACE TRAVEL: A Reply to Professor Dingle*

By R. Herman,† B.Sc., Grad.I.E.E., Fellow

(Communication from the Radio Research Department of The Plessey Company, Ltd.)

SUMMARY

An answer is given to Professor Dingle's argument[2] that if a spaceship were to travel away from the Earth at a velocity comparable with that of light and subsequently return, then the duration of the two-way journey, as measured by a clock in the spaceship, would be substantially the same as that measured by a clock on the Earth.

It is shown in the paper that the correct statement corresponding to the postulate of general relativity is that all co-ordinate systems are equivalent for the formulation of the general laws of nature, and that this does not imply complete equivalence between all frames of reference. An account of the journey is given, as viewed by an observer in the spaceship, which demonstrates that a difference between the clock readings would indicate non-equivalence between the Earth and the spaceship as origins for defining a frame of reference, but that an observer at either origin would be entitled to regard himself as at rest. Professor Dingle's statement concerning the specification of space-time is then discussed and the concept of space-time is explained. It is shown that an inertial frame of reference can be rigorously specified on a practical basis, but an exact specification in terms of its relationship to the rest of the universe presents certain fundamental difficulties.

In the final section, Professor Dingle's statement about absolute motion is considered. It is explained that a misunderstanding may have been caused by the fact that the postulates of special relativity appear to imply that nature provides no phenomenon corresponding to uniform motion of an observer relative to the rest of the universe, but that this is a false deduction arising from the fact that the phenomena whereby such motion could be detected are outside the scope of the special theory. The nature of the phenomena, whereby an observer in a closed laboratory could theoretically detect his motion relative to the rest of the universe, is indicated, although in practice the measurements required would probably be beyond the resolution of his instruments. Nevertheless, at a sufficiently high velocity, effects would be produced on the shell of a space vehicle which are likely to set an upper limit to this velocity.

One of the predictions of the special theory of relativity is that if an observer is in uniform translational motion relative to a second observer, who is at rest with respect to an inertial frame of reference, then the dial readings of the

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first observer's clocks will appear to the second observer to advance by only $(1 - v^2/c^2)^{1/2}$ units for each unit increment on the dials of his own clocks, where v is the relative velocity of the two observers and c is the velocity of light. Similarly the first observer will consider that the second observer's clocks are going slow by the same factor, and each observer is equally entitled to his own opinion. If, on the other hand, the first observer were to move in such a way that his position coincided with that of the second observer on two occasions, then it is deduced that there would be a real discrepancy in the time intervals separating these events as recorded by the pocket watches of the two observers. An example given in a book by Sir George Thomson[1], of a return journey to the nearest star, α Centauri, taking $14\frac{1}{2}$ years according to clocks in the spaceship, but during which the space traveller's twin brother on the Earth would age by just over 17 years, has recently been the subject of somewhat heated debate. Professor Dingle[2] believes that the theory of relativity has been misinterpreted and has argued that any real discrepancy in the readings of the two clocks, which depended only on their relative motion, would be inconsistent with the postulate of relativity. He admits[3] the possibility of a very small discrepancy, of the order of one second in a hundred years, depending on the force acting on the clocks in the spaceship while the rocket motor is in operation but independent of the total duration of the journey. Dr. Essen has supported Professor Dingle's conclusion that there would be no significant difference between the clock readings, but considers[4] that there is an error in Einstein's original paper. Other participants[5] in the controversy have rejected Professor Dingle's argument, but Professor Dingle maintains[6] that his argument has been bypassed instead of being answered. I have therefore endeavoured to provide detailed answers to those points in Professor Dingle's argument which have not already been answered adequately, and to clarify certain aspects of relativity which have been a source of misunderstanding. The rest of the paper is in four sections, which relate respectively to four statements which have been made by Professor Dingle.

(1) *General relativity asserts that all co-ordinate systems are equivalent*[7].

Professor Dingle has omitted part of Einstein's statement[8] of the postulate of general relativity, *viz.*, "All Gaussian co-ordinate systems are essentially equivalent for the formulation of the general laws of nature."‡ Equivalence for the formulation of the general laws of nature does not imply equivalence between all corresponding observations. For complete equivalence it is necessary to

‡ It seems to me that this postulate should be preceded by an additional postulate, *viz:* that it is possible, at least in theory, for any observer to construct a frame of reference having the form required for specifying a Gaussian co-ordinate system. This implies constructing a three-dimensional framework of short, rigid, standard rulers with standard clocks attached at each intersection, such that any event within the frame is uniquely specified by the scale readings on the three rulers and the clock which are coincident with the event, and such that these readings form four continuous sets along any particle trajectory. It is not assumed that the framework as a whole is rigid. It may be questioned whether it is entirely self-evident that this construction should always be possible and the additional postulate should therefore be stated explicitly and not just assumed. This may seem unnecessarily pendantic, but I think that a lot of the argument which the theory of relativity has produced has been due to insufficient clarity in the statement of the postulates.

consider a restricted set of special observers such as the set of "fundamental" observers considered in cosmological theories[9] for whom the Universe, when viewed on a sufficiently large scale, always presents an isotropic appearance. A space travel experiment is impossible between two fundamental observers, since their relative velocity is not arbitrary but is a definite function of their relative positions, but if each possessed a twin they could carry out similar experiments by sending their respective brothers on similar rocket journeys.

(2) *If, after the separation and subsequent reunion of two clocks, one were retarded by a quantity depending on their relative motion and the other not, that phenomenon would show that the first had moved and not the second, and hence would be inconsistent with the postulate of relativity*[10].

A discrepancy between the clock readings would indicate a lack of equivalence between the two frames of reference relative to which the two clocks were respectively stationary. It would not, however, show which clock had moved, since an observer who remained stationary with respect to the first clock could claim that the discrepancy was due to the movement and consequent advancement of the second clock. The manner in which the general theory of relativity provides a justification for this claim is perhaps best explained in the form of an argument between two observers when the first observer (M) has just returned from a visit to α Centauri while his twin brother (R) has remained on the Earth:

M.: "You seem to have aged a lot while you have been away, and your clock is reading more than $2\frac{1}{2}$ years in advance of Spaceship Standard Time. You should have stayed with me in the spaceship."

R.: "Are you suggesting that it is *I* who have been travelling and that it is *my* clock which is in error? How then can you account for the fact that my clock has been going faster than yours instead of slower?"

M.: "Quite easily. When a gravitational field is present a moving clock—or for that matter a stationary clock—may go either slow or fast depending on the magnitude and direction of the field as a function of position and time, and on the path or position of the clock. During the initial and final stages of your journey your clock *was* going slow, but for part of your journey the rate of your clock increased owing to the gravitational field which I generated when α Centauri came near my rocket."

R.: "I did not observe the rate of my clock increase, nor did I detect a gravitational field. And how could you generate one?"

M.: "I generated the gravitational field by operating my rocket motor, but you did not detect it because you were accelerating with the field, together with all the material in the universe except my rocket. I did not accelerate, however, since the force on my rocket due to the pressure of the gas in the combustion chamber and nozzle of the rocket just balanced the force due to the gravitational field. In consequence of this field, the rate of every clock in the universe, except mine, was altered, the total change in reading produced depending on its distance and bearing from my rocket. Distant clocks such as yours, which were accelerated towards my rocket, were advanced by a large amount, whereas clocks which were accelerated away from my rocket were retarded. You were unaware of this because the rate of your biological processes increased by the same factor as the clocks in your vicinity, and you did not allow for the effects of the gravitational field when comparing these clocks with other clocks far away from you."

R.: "But I still do not understand how your rocket could accelerate the whole universe, and why you should have gained time."

M.: "You forget that, according to the postulate of relativity, inertia is not an intrinsic property of a particular body, but is only a measure of a reciprocal relationship existing between that body and the rest of the material in the universe.[11] The inertia of the *whole* universe is therefore a meaningless concept, since you cannot apply a force to it and there is nothing with respect to which you can measure its acceleration. The inertial mass of the universe with my rocket excluded is, however, equal to the quantity which you, believing the universe to be stationary, considered to be the inertial mass

of my rocket. I have not gained any time—I have only, by operating my rocket, prematurely aged everyone else. All this is quite simple to achieve providing only that you have a rocket and the necessary faculty for not being bemused into doubting your immobility."

It is seen that the general theory of relativity allows one to describe a spaceship either as a device for moving its occupant or as a device for moving the rest of the universe, but it does not allow one to regard the spaceship and the Earth as origins of equivalent frames of reference. This is to be expected since we are concerned with a three body problem, *viz.*, the spaceship, the Earth, and the rest of the material in the universe. It may seem however, that the description which has been given is open to criticism on philosophical grounds since it may be questioned whether it is logically permissible for *M.* to ascribe an increase in the rate of *R.'s* clock to a gravitational field which *R.* cannot detect. This is partly the result of avoiding the mathematically more elegant description in terms of the world-lines of the two observers referred to a four-dimensional co-ordinate system. It is also, I believe, partly due to a misunderstanding which has arisen owing to the terminology introduced by Einstein in an attempt to avoid confusion with ideas based on the pre-relativistic concept of universal time. The following discussion will, I hope, help to clarify these points.

Suppose that two cars, the milometers of which are initially set at the same reading, travel along different roads to the same place. No one would be surprised if the readings of the two milometers did not agree at the destination, and the discrepancy would not be ascribed to an increase or a decrease in the scale factor (*i.e.*, the increment in scale reading per unit distance) of one milometer, since it is a matter of common experience that the distance between two points is not an invariant. Now, according to the theory of relativity, a clock is a device which measures the time extension along its world-line, *i.e.*, *proper-time*, unit intervals of which, are defined by unit changes in the scale reading of a standard clock having the same world line. It is a fundamental result of the theory, although contrary to common experience, that the proper-time interval between two events is not an invariant when measured along different world-lines. The scale factor of a clock, is, therefore, its *proper-rate*, *i.e.*, the increment in its scale reading per unit interval of proper-time. There is, however, an ambiguity in the meaning of the word "rate," as applied to a clock, when there is no qualifying adjective. Before the advent of relativity, this was synonymous with "scale factor" or "increment in scale reading per unit time," since it was thought that time was absolute and therefore that the relative position or velocity of the standard clock used for comparison, was irrelevant. In the theory of relativity it has been shown that these assumptions are invalid, and the word "rate" has been used, perhaps unwisely, to signify the quantity obtained by dividing an increment in scale reading of a distant clock by a corresponding interval of proper-time measured by a local clock. This quantity is not an invariant for a given pair of clocks, and is arbitrary in the sense that it depends upon the particular procedure chosen for relating the scale readings of the two clocks. Nevertheless, it is evident that the proper-time interval recorded by a clock between the events of its separation from and reunion

with another clock— which is not an arbitrary quantity—may be deduced without ambiguity by integrating the rate of the first clock with respect to the time scale of the second clock, throughout the interval, providing that the procedure adopted for relating the scale readings of the two clocks gives a one to one correspondence between them. It would seem probable that if the theory of relativity had been formulated immediately after the invention of clocks, the words "time" and "rate" would have been used instead of the expressions "proper-time" and "proper-rate" while a phrase such as "transferred rate" or "projected rate" would have been introduced to convey the present relativistic meaning of the world "rate." Much of the present controversy might then not have occurred.

(3) *The paths of the clocks have been considered (by those who believe in asymmetry between the clock readings) as world-lines in some specifiable space-time, but those who reason in this way have omitted to specify the space-time and to show that the paths in the problem differ by the assigned amount*[12].

The world-lines refer, in the first instance, to a particular co-ordinate system, but provided that all the co-ordinate systems which are used are properly derived, certain attributes of world-lines are invariant with respect to transformations from one co-ordinate system to another. To specify such a co-ordinate system it is first necessary to construct, or to postulate the construction of, a frame of reference in the sense of a physical structure consisting of a network of standard measuring rods and standard clocks, whereby a set of four numbers may be assigned uniquely to any localised event occurring within the framework. The event may then be represented mathematically as a point in a four-dimensional co-ordinate system, while the existence of a particle within the framework, for a finite period of time, may be represented as a line in the co-ordinate system, which is referred to as a world-line. This allows laws of dynamics relative to the frame of reference to be translated into geometrical equations referred to the co-ordinate system, and vice versa. Substitution of one frame of reference for another then corresponds, for the description of events and particle trajectories which are common to both, to a mathematical transformation from one co-ordinate system to another, the equations for transforming the co-ordinates depending on the choice of the frames of reference and the manner of deriving the co-ordinate systems. In the context of special relativity, these equations take a particularly simple form if the frames of reference are both inertial, and if in deriving the co-ordinate systems, the real time variable t indicated by the clocks is replaced by the imaginary variable ict where $i = (-1)^{1/2}$ and c is the velocity of light. In addition, the separation between any two points in either of these co-ordinate systems, defined in the same way as for a Cartesian co-ordinate system in Euclidean space, *viz.*, such that the square of the separation is equal to the sum of the squares of the differences in the co-ordinates, is then invariant with respect to the transformation. The distance and time intervals between the corresponding events are not however the same in the two frames of reference. This contrasts with the geometrical representation of classical dynamics, for which the separation

between two points in any co-ordinate system may be resolved into distance and time components which have the same significance for all frames of reference. A co-ordinate system as used in the representation of relativistic dynamics is therefore described as a system of *space-time* co-ordinates rather than a system of *space and time* co-ordinates. The word *space-time* is also used as a noun to signify a concept which relates to a system of space-time co-ordinates in a manner which is analogous to that in which the concept of space relates to a system of space co-ordinates. In other words, events are thought of as embedded in a four-dimensional continuum which cannot be objectively resolved into separate space and time dimensions. Professor Dingle is entitled, if he wishes, to question the merits of this concept, but this cannot affect the validity of the mathematical analysis, since the concept has only been formed afterwards, in order to provide a descriptive account of the theory.

To complete the specification of the co-ordinate system to which the world-lines of the clocks have been referred, it is necessary to specify a procedure for setting up an inertial frame of reference. To do this we start with an observer who is not subject to a gravitational field, *i.e.*, if he releases an object it does not accelerate away from him. He then sets up a system of Cartesian distance co-ordinates by means of rigid standard rulers. After this he fixes standard clocks at each intersection of the rulers and checks that these are synchronized by transmitting light flashes. The clocks are defined as being in synchronization if the time seen on each clock is equal to the mean of the times of transmission and reception of the light pulse used to illuminate it. Any event within this framework is then specified by the scale readings of the clock and the three rulers coinciding with the event. If the event is accompanied by a flash of light these figures may be read by any observer within visual range irrespective of his position, or his velocity, relative to the frame of reference. Finally, if the equations of special relativity are to be applicable, it is necessary to check the limits of the region within which the reference frame has an inertial character. This may be accomplished by projecting particles in various directions and observing the distances up to which these move in straight lines at constant velocity, as deduced from the readings of the clocks and rulers at successive points along the trajectory of each particle. Since an inertial frame may also have a limited extension in time (for example, an inertial frame of reference constructed in a lift after the supporting cables have broken, is no longer inertial after the bottom of the lift shaft has been reached) it is necessary to repeat the tests at frequent intervals.

In the space travel experiment $M.$ may, if he wishes, plot both his own and $R.$'s world-lines using $R.$'s frame of reference, and his plots will then be identical to those obtained by $R.$ He may regard either himself or $R.$ as at rest, and his choice has no bearing on his judgment as to the inertial character of the reference frame. Alternatively, he may choose a non-inertial frame of reference, relative to which he remains stationary. Should he, however, insist on providing himself with a frame of reference which is both inertial, and stationary with respect to his rocket, he may construct one whenever his rocket motor is inoperative, but must discard it and construct a new one after each operation

of the motor. Owing to the time required for constructing each new frame of reference, there will be gaps in his records of the positions and readings of *R.'s* clocks. Two possible procedures whereby these gaps might be filled in are as follows:

(i) He might compute the missing points on his graphs by extrapolation, restricting any unavoidable discontinuities to the time values, in his own reference system, corresponding to the operations of his rocket motor. It is convenient in the present instance, to assume that each operation of the motor is sufficiently short for it to be represented as a single impulse.

(ii) Before separating from *R.* he could arrange for assistants to construct all the frames of reference he would require. As he enters each new frame of reference, an assistant in the new frame could hand over a record of past observations in this frame, while another assistant could remain in the old frame to record the awaited reflections from light signals already transmitted. The second assistant could later transmit this information to *M.* by radio.

Either of these procedures would show that *R.* had "cheated" by resetting all his clocks by differing amounts each time *M.* was preoccupied with the task of changing his frame of reference. In other words, these procedures for relating the scale readings of the clock adjacent to *R.* to the scale readings of the clock in the rocket, do not give a one-to-one correspondence between them.

A practical specification for an inertial frame of reference has now been given and this has confirmed the absolute nature of the distinction between *M.* and *R.*. It has not, however, been shown in detail how the particular character of any given frame of reference is determined by its relationship to the rest of the universe. For a complete physical understanding of the problem, a method is required for defining a universal frame of reference, and for computing the field pattern relative to this frame in terms of the distribution and movement of matter. A specification for any local inertial frame of reference could then be derived analytically.

A partial solution to this problem is provided by Weyl's postulate,[13] *viz.*: "The particles of the substratum (representing the nebulæ) lie in space-time on a bundle of geodesics diverging from a point in the (finite or infinitely distant) past." This leads to the conclusion that the motion of the fundamental particles defines, at each point, a local inertial system, and to a specification of the relative motions of different parts of the substratum as a co-moving co-ordinate system.[14] This specification, however, refers to an idealized model of the universe in which the irregularities in the distribution of matter are not taken directly into account. A similar difficulty arises in relation to the tensor field equations of general relativity[15]. In order to derive the metric in a perturbed region, *e.g.*, in the vicinity of the Sun, it is necessary to postulate boundary conditions and then to solve the equations. Since the co-ordinates in the equations involve both the intrinsic characteristics of the region and the arbitrary properties of the frame of reference, there does not appear to be any way of finding a solution unless it is postulated as the boundary condition that space is undisturbed at infinity, *i.e.*, that the perturbing body is embedded in an otherwise perfectly uniform universe. Because of the large scale uniformity

of the universe[16], and the very large ratio of interstellar distances to stellar diameters, this assumption does not in general introduce significant error. Nevertheless, it has not proved possible to derive a direct specification of the field in terms of the actual distribution and movements of material bodies.

This may be only a reflection of the limited state of our present mathematical or physical knowledge, or alternatively, it may be necessary to reject the postulate of relativity and assign to space certain intrinsic properties. Neither view, however, lends support to Professor Dingle's arguments concerning the behaviour of clocks.

(4) *That the postulate of relativity asserts that Nature provides no phenomenon corresponding to absolute rest (later extended to cover motion in general)*[10].

This statement is correct in the sense that the general theory of relativity is based on the postulate that the laws of nature may be formulated in such a way that any observer may regard himself as at rest, but this does not imply that the motion of an observer with respect to the rest of the material in the universe is unobservable, and it does not lead to any parodox. The postulates on which the special theory of relativity is based may, however, appear to give rise to certain contradictions. These postulates are properly expressed as follows:

(*i*) It is possible to construct a frame of reference extending over a limited region, which is inertial to within the limits of accuracy of any measuring instrument, such a frame being defined as one in which Newton's laws of motion are obeyed and relative to which no gravitational, electrical or magnetic fields exist.

(*ii*) The laws of nature are invariant with respect to a Lorentz transformation to a second frame of reference in uniform translational motion relative to, and within, the first frame.

The apparent contradictions arise as follows. Since, by definition, no fields other than the inertia field exist with respect to any inertial frame of reference, and since from the second postulate it follows that the second frame is also inertial and is equivalent to the first for the formulation of the laws of nature, the two frames must be completely equivalent as there are no parameters left with respect to which they might differ. It therefore appears to be justifiable to express the second postulate in the form: "Nature provides no phenomenon corresponding to uniform translational motion relative to an inertial frame of reference." Since the first frame may be chosen so that its origin is stationary relative to the substratum it is a corollary that: "Nature provides no phenomenon corresponding to uniform translational motion relative to the substratum." This, however, is clearly erroneous because the anisotropy in the large-scale aspect of the universe, whereby motion relative to the substratum may be determined, is in fact such a phenomenon. If this particular phenomenon is excluded we are then left with the proposition: "Nature provides no phenomenon, observable within a closed laboratory, corresponding to uniform translational motion relative to the substratum." The difficulty in accepting

this proposition is that acceleration with respect to the substratum does produce effects, which are observable in a closed laboratory, in the form of a gravitational field having a characteristic type of configuration. Given a sufficiently large laboratory and sufficiently accurate measuring instruments, such a field can in principle always be distinguished from a gravitational field arising from proximity to a massive body of finite dimensions, if the spatial and temporal distribution of the field within the laboratory is investigated.[17] Consequently, if the proposition is true, we are led to the conclusion that velocity relative to the substratum is an unobservable and therefore meaningless entity so far as the inhabitants of the laboratory are concerned, but that changes in the value of this entity are significant. This may not be a true paradox in the mathematical sense, but is nevertheless a very unsatisfactory conclusion from the philsophical point of view.

Further reflection indicates that the reasoning in the preceding paragraph is subject to criticism. Firstly, visual observation of extragalactic nebulæ implies that electromagnetic radiation due to an external source is present within the postulated inertial frame of reference, and any such radiation, however small, is not strictly allowable within the definition of an inertial frame. Secondly, the ability to distinguish between gravitational fields due to acceleration relative to the substratum and other types of gravitational field, within a closed laboratory, depends on the size of the laboratory being very great, whereas an inertial frame of reference is postulated only for a limited region. In other words, motion of any form relative to the substratum, or any other universal frame of reference, is indeed unobservable according to the Special Theory of relativity, but only because those phenomena whereby such motion might be detected are specifically excluded from the scope of this theory.

In view of the misunderstanding which has occurred, a further clarification of the status of the Special Theory and its relation to the General Theory is perhaps desirable. The central feature of the former theory is the concept of an inertial frame of reference. As Einstein has explained,[18] such a frame cannot be extended over an indefinitely large region of space-time and should always be regarded as only an approximation over a small region. In this context, however, the word "small" means small by cosmological standards, but not necessarily by terrestrial standards. The *a priori* experimental basis for accepting the first postulate, and the justification for applying the results of the theory to a space journey as extended as that to α Centauri, is that astronomical observations have indicated that a frame of reference can be selected relative to which Newton's laws of motion are obeyed, to within a very close approximation, up to distances which are very large by terrestrial standards. Nevertheless, the observed recession of distant galaxies which is inferred from the red shift in the light received, and which according to most cosmological theories must be an accelerated recession, suggests that Newton's laws may not be obeyed over cosmological distances. In the General Theory, the principle of equivalence between observers for the formulation of the laws of nature is extended to include gravitational phenomena and so to include all observers except where electrical or magnetic fields are involved. This is achieved at the

cost of losing the complete equivalence between all observers who are either stationary or in uniform translational motion relative to a selected frame of reference, which applies in the Special Theory. The field equations of the General Theory do, however, possess a solution corresponding to an expanding universe in which matter is uniformly distributed throughout space, and complete equivalence is then obtained between all observers who are stationary relative to the material particles in their vicinity. At the opposite extreme in the scale of magnitude, the equations can be reduced to those of the Special Theory for an infinitesimally small world element.

Let us now examine the practical implications of the foregoing discussion. Suppose first of all that one observer is at rest relative to a local inertial frame of reference and that a second observer moves past the first with uniform relative velocity. Since the inertial frame of the first observer is valid only as an approximation over a limited region, and since the separation between the two observers will increase indefinitely with time, it cannot be assumed that the two observers are exactly equivalent. Now consider instead the situation in which two observers, each moving in a free path, pass one another with a high relative velocity. If the expansion of the universe is taken into account, it would appear that the velocity of separation of the observers should be augmented by this expansion, *i.e.*, it should be accelerated. Let the first observer be assumed stationary with respect to the substratum. A simple, but perhaps insufficiently rigorous analysis, then indicates that the acceleration of the second observer as measured by the first should be initially $HV[1 - (V^2/c^2)]$, where V is the initial velocity of separation and H is Hubble's constant (5×10^{-18} sec.$^{-1}$ approximately). This relation appears to supply the missing connection between velocity and acceleration relative to the substratum, and shows that the reference frames of the two observers are not accurately connected by a Lorentz transformation. We may therefore expect that effects should exist within the frame of reference of the second observer which should theoretically enable him to determine his velocity relative to the substratum, although in practice these effects would probably be beyond the resolution of his measuring instruments. It may be anticipated that the phenomena would take the form of a small acceleration, relative to the observer, of freely moving high-speed particles, or of light beams, which would be anisotropic to an extent depending on the velocity of the observer relative to the substratum.

By way of conclusion it may be of interest to look sufficiently far into the future to a time when space travel to remote parts of the Milky Way may be envisaged. If such a journey is to be completed within the traveller's lifetime it will be necessary for the rocket to travel relative to the substratum at a velocity almost equal to that of light. Even so, it might not be possible for the traveller to detect the resulting distortion in the geometry of the space-time region within the vehicle, but other effects will probably be significant. Collisions with interstellar dust particles and gas molecules, and with photons radiated by the surrounding stars, will generate heat in the shell of the rocket and will give rise to a retarding force, the mean values of which will increase with the velocity relative to the substratum. Even if it should prove possible to design a rocket

power plant giving the required total impulse and to provide adequate temperature controlling equipment, the problem will remain of protecting the vehicle against damage due to collisions with the larger dust particles. If intergalactic travel should ever be contemplated, the problems may be even more severe, owing to the still greater velocity which will be necessary, in spite of the relative emptiness of intergalactic space. Evidently, for travel through space, as through any other medium, a velocity is eventually reached beyond which increased effort in vehicle design gives diminishing returns in performance.

Finally, perhaps I ought to make it clear that I am not acquainted with the proofs of all the statements by other writers which I have quoted or paraphrased. My object has been only to show that these statements are logically consistent, and to use them in formulating an argument whereby the apparent contradictions associated with the relativistic contraction of time may be resolved. Professor Dingle has stated,[12] however, that what is needed here is not mathematics, but a faculty for not being bemused by mathematicians, and that this seems to be a rare faculty. Readers may be relieved to know that they do not require this rare faculty for assessing the merits of this contribution.

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SOME DESIGN PARAMETERS OF A SIMPLIFIED ION ROCKET*

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(Communication from the National Research Council, Canada)

SUMMARY

Equations used in a recent paper[1] on the design of ion rockets are derived. The special cases of constant acceleration and constant exhaust velocity are considered.

LIST OF SYMBOLS

A	acceleration (constant with time)
$\bar{A}$	average acceleration
A_t	acceleration at time t
d	fraction of M_0 assigned to structure and payload
f	fraction of M_0 assigned to propellent
I_{0a}	specific impulse
K_1	overall specific mass of power plant
$K_2 f$	fraction of initial mass assigned to propellent containers
M	instantaneous mass of the rocket
M_d	mass of structure and payload
M_f	initial mass of propellent
M_p	mass of power plant
M_0	initial mass of rocket
p	fraction of M_0 assigned to power plant
P	effective power output in the exhaust
R	mass ratio of rocket $(M_0/(M_0 - M_f))$
S_b	total distance traversed under power
S_0	transfer distance
S_1, S_2	distances travelled during first and second periods under power
t	time
t_b	total time under power
t_0	transfer time
t_1, t_2	times of first and second periods under power
V_c	characteristic velocity
V_e	exhaust velocity
x	fraction of M_0 assigned to the propulsion system
ϕ	a function of f defined by equation (19)

Introduction

A recent paper[1] dealing with certain aspects of the design of ion rockets presented a number of equations without deriving them. This avoided undue breaking up of the text or the inclusion of lengthy appendices but made it necessary to substitute, to some extent, statement for argument. The present paper fills in the more important of these lacunae and may also serve to demonstrate a method of investigating the properties of a simplified ion rocket.

In such a rocket it is assumed that the effective power output ($P = \frac{1}{2}\dot{M}V_e^2$) is independent of exhaust velocity (V_e) and proportional to power plant mass

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(pM_0), the mass of the propellent containers (K_2fM_0) is proportional to the mass of propellent initially carried (fM_0) and the power available is not time-dependent; there are grounds for supposing[2] that the actual properties of an ion rocket would be such as to justify the adoption of these assumptions in a preliminary design study. Additionally, restrictions have been placed on the variation of exhaust velocity with time in order to simplify this study; these have been discussed elsewhere[1,2] and will not be further dealt with here.

Fundamental Relations

We may consider an ion rocket to have an initial mass (M_0) composed of the power plant (M_p), propellent (M_f), propellent tanks (K_2M_f) and remaining (*i.e.*, structure plus payload) mass M_d. The fractional masses p, f, K_2f and d (where $p = M_p/M_0$, etc.) will more commonly be used, and so we have the relations:

$$\left.\begin{aligned} M_p + M_f(1 + K_2) + M_d &= M_0 \\ \text{and} \qquad p + f(1 + K_2) + d &= 1 \end{aligned}\right\} \quad .. \quad .. \quad (1)$$

Where P is the effective power in the exhaust, K_1 is the specific mass of the power plant (i.e., the number of units of mass required to produce one unit of power in the exhaust), M is the instantaneous mass of the rocket and V_e is the mean velocity of the exhaust, we have the additional relations:

$$\frac{M_p}{K_1} = \frac{pM_0}{K_1} = P = -\tfrac{1}{2}\dot{M}V_e^2 \quad .. \quad .. \quad (2)$$

$\dot{M}$, since the rocket loses mass, being negative.

For an acceleration (in field-free space) of A_t at time t we have:

$$A_t = -\frac{V_e\dot{M}}{M} = \frac{\sqrt{-2P\dot{M}}}{M} = \frac{2P}{V_eM} \quad .. \quad .. \quad (3)$$

and

$$V_c = \int_0^{t_b} A_t\,dt = \int_{M_0}^{M_0(1-f)} -\frac{V_e\,dM}{M} \quad .. \quad .. \quad (4)$$

where V_c is the characteristic velocity and t_b is the firing time of the rocket. Equations (1) to (4) are valid for any ion rocket and are independent of any variation in M, V_e or P with time.

Constant Exhaust Velocity

If we now suppose that P and V_e (and hence $\dot{M}$) are not time dependent, we have the relation:

$$-\dot{M} = \frac{M_0f}{t_b} \quad .. \quad .. \quad .. \quad .. \quad (5)$$

and, from equation (4), the characteristic velocity:

$$V_c = -V_e \ln (1-f) \quad .. \quad .. \quad .. \quad (6)$$

This is a form of the well-known fundamental rocket equation:

$$V_c = V_e \ln R \quad .. \quad .. \quad .. \quad ..$$

where R is the mass ratio. Equations (2), (5) and (6) combine to give the relations:

$$\frac{f V_e^2 K_1}{2 p t_b} = \frac{f V_c^2 K_1}{2 p t_b \ln^2 (1-f)} = 1 \quad .. \quad .. \quad .. \quad (7A)$$

which can be rewritten:

$$V_c \bar{A} = \frac{V_c^2}{t_b} = \frac{2 p \ln^2 (1-f)}{K_1 f} \quad .. \quad .. \quad .. \quad (7B)$$

where $\bar{A}$ is the average acceleration during firing. The left-hand sides of equation (7B) contains what might be called the mission's requirements and the right-hand side the rocket's offer: they must, of course, be reconciled to one another.

Constant Acceleration

If instead of the exhaust velocity the acceleration is made constant we can rewrite equation (3) in the form:

$$\frac{\dot{M}}{M^2} = -\frac{A^2}{2P}$$

which on integration gives:

$$\frac{1}{M} = \frac{A^2 t}{2P} + C$$

At $t = 0$, $M = M_0$ and at $t = t_b$, $M = M_0 - M_f$ and so we can write

$$A^2 = \frac{2P M_f}{t_b M_0 (M_0 - M_f)} = \frac{2 p f}{K_1 t_b (1-f)}$$

which can be rewritten to correspond with the form of equation (7B) as:

$$V_e A = \frac{V_c^2}{t_b} = \frac{2 p f}{K_1 (1-f)} \quad .. \quad .. \quad .. \quad (8)$$

Mass Distribution

(a) *Constant exhaust velocity*

The optimum distribution of mass between propellent and power plant depends on a number of factors. As an illustration we will find the mass distribution giving maximum V_c^2/t_b (a very proper endeavour since this is an important performance factor) for certain design restrictions. We will first

suppose that a fixed proportion of the rocket's initial mass is allocated to the propulsion system, *i.e.*, that d [$= 1 - p - f(1 + K_2)$] is a constant. For constant V_e (and K_2) we then differentiate equation (7B) to obtain:

$$\frac{d(V_c^2/t_b)}{df} = \left\{ -f(1+K_2)\ln^2(1-f) - \frac{2fp\ln(1-f)}{1-f} - p\ln^2(1-f) \right\} \frac{2}{f^2 K_1}$$

which gives for maximum V_c^2/t_b:

$$-\ln(1-f) = \frac{2fp}{[p + f(1+K_2)]\,(1-f)} \qquad .. \qquad .. \qquad (9A)$$

or

$$p = \frac{-f(1-f)\,(1+K_2)\ln(1-f)}{2f + (1-f)\ln(1-f)} \qquad .. \qquad .. \qquad (9B)$$

Substituting this value of p into equation (7B) we obtain V_c^2/t_b as a function of f:

$$\frac{K_1 V_c^2}{t_b} = \frac{-2(1-f)\,(1+K_2)\ln^2(1-f)}{2f + (1-f)\ln(1-f)} = \frac{8p^2 f\,(1+K_2)}{(f+p)^2\,(1-f)^2} \qquad .. \qquad (10)$$

If instead of maintaining d constant our restriction is that M_f only is variable, *i.e.*, that the optimum quantity of propellent (and tanks) is to be found, we can similarly write:

$$\frac{d(V_c^2/t_b)}{dM_f} = \left\{ \frac{2M_f(M_p + M_d)}{(M_0 - M_f)\,M_0} - \ln\left(\frac{M_0}{(M_0 - M_f)}\right) \right\} \frac{2M_p \ln[M_0/(M_0 - M_f)]}{K_1 M_f^2}$$

so that for maximum V_c^2/t_b we have:

$$-\ln(1-f) = \frac{2f\,(p+d)}{1-f} = \frac{2f[1 - f(1+K_2)]}{1-f} \qquad .. \qquad (11A)$$

which for $K_2 = 0$ goes to

$$-\ln(1-f) = 2f \qquad .. \qquad .. \qquad .. \qquad (11B)$$

This latter relation is satisfied when $f = 0{\cdot}797$, which in turn gives a value of 6·376 for $K_1 V_c^2/pt_b$.

(*b*) *Constant acceleration*

The optimum mass distributions for constant acceleration can be found from equation (8) in a similar manner. For our first restriction of constant d we have:

$$\frac{d(V_c^2/t_b)}{df} = \frac{2}{K_1}\left\{ \frac{1 - d - 2f(1+K_2) + f^2(1+K_2)}{(1-f)^2} \right\}$$

so that V_c^2/t_b is a maximum when:

$$p = f(1-f)\,(1+K_2) \qquad .. \qquad .. \qquad .. \qquad (12)$$

which substituted into equation (8) gives:

$$\frac{V_c^2}{t_b} = \frac{2f^2(1+K_2)}{K_1} \qquad .. \quad .. \quad .. \quad (13A)$$

It may be convenient to determine V_c^2/t_b as a function of the fraction of the rocket's mass that is devoted to propulsion. If we call this fraction x $[=p + f(1 + K_2)]$, equation (13A) can be rewritten in the form:

$$\frac{V_c^2}{t_b} = \frac{2}{K_1}(1+K_2)\left(1-\sqrt{1-\frac{x}{1+K_2}}\right) \qquad .. \quad .. \quad (13B)$$

If, as in the corresponding case for constant V_e, we now take our second restriction in which M_f only is variable, we obtain:

$$\frac{d(V_c^2/t_b)}{dM_f} = \frac{2M_p}{K_1}\left\{\frac{(M_p+M_d)^2 - M_f^2 K_2(1+K_2)}{M_0^2(M_0-M_f)^2}\right\}$$

so that a maximum for V_c^2/t_b is reached when:

$$f = \frac{p+d}{\sqrt{K_2(1+K_2)}} \qquad .. \quad .. \quad .. \quad (14)$$

When $K_2 = 0$ the maximum is at $M_f = \infty$, i.e., there is then no optimum mass of propellent, V_c^2/t_b increasing monotonically with M_f.

Transfer Times

(a) *Transfer with continuous thrust*

The transfer time (t_0) and the acceleration programme of the rocket must be considered together. In the simplest (and most wasteful) case the thrust is applied with constant exhaust velocity for the entire transfer distance (S_0), the rocket accelerating continuously to a velocity of $V_c/2$ and then decelerating until it reaches zero velocity. If we use the subscripts 1 and 2 respectively for these two manoeuvres and 0 for the voyage totals, we have the relations:

$$t_1 + t_2 = t_b = t_0, \qquad S_1 + S_2 = S_b = S_0, \qquad f_1 + f_2 = f$$

$$\frac{V_e}{2} = -V_e\ln(1-f_1) = -V_e\ln\left(1-\frac{f_2}{1-f_1}\right) = -\frac{V_e}{2}\ln(1-f)$$

from which it can be seen that $f_1 = 1 - \sqrt{1-f}$ and $f_2 = \sqrt{1-f} - (1-f)$ and therefore $t_1 = (1-\sqrt{1-f})\,t_b/f$ and $t_2 = [\sqrt{1-f} - (1-f)]\,t_b/f$. The distances travelled during the two manoeuvres are given by:

$$S_1 = \int_0^{t_1} v\,dt = -V_e \int_0^{t_1} \ln\left(1 - \frac{ft}{t_b}\right) dt$$

$$= \frac{V_e t_b}{f}\left[\left(1 - \frac{ft}{t_b}\right)\ln\left(1 - \frac{ft}{t_b}\right) - \left(1 - \frac{ft}{t_b}\right)\right]_0^{t_1}$$

S_2 is obtained by changing the limits to t_b and t_1 and subtracting the result from $V_e t_2/2$. We then have for the two cases:

$$S_1 = \frac{V_e t_b}{f}\left\{\frac{1}{2}\sqrt{1-f}\ln(1-f) - \sqrt{1-f} + 1\right\}$$

$$= -\frac{V_e t_b}{f}\left\{\frac{1}{2}\sqrt{1-f} + \frac{1-\sqrt{1-f}}{\ln(1-f)}\right\} \quad .. \quad .. \quad (15A)$$

and similarly:

$$S_2 = \frac{V_e t_b}{f}\left\{\frac{1}{2}\sqrt{1-f} - \frac{1-f-\sqrt{1-f}}{\ln(1-f)}\right\} \quad .. \quad .. \quad (15B)$$

On adding we get:

$$S_0 = S_b = S_1 + S_2 = -\frac{V_e t_b\,(2-f-2\sqrt{1-f})}{f\ln(1-f)} \quad .. \quad (16A)$$

which, by substitution from equation (7B), can be rewritten

$$t_b = \left\{\frac{S_0^3 f^3 K_1}{2p\,(2-f-2\sqrt{1-f})^2}\right\}^{\frac{1}{4}} \quad .. \quad .. \quad .. \quad (16B)$$

Optimum mass distributions can be found as in the previous cases. For example, if we again impose the restrictions of constant d and K_2 with S_0 and K_1 supposed fixed we find, from putting $\frac{dt_b}{df} = 0$, that:

$$p = \frac{f\,(1+K_2)\,(2-f-2\sqrt{1-f})}{2f\left(\frac{1}{\sqrt{1-f}} - 1\right) - 3(2-f-2\sqrt{1-f})} \quad .. \quad (17)$$

Fig. 1 has been derived from equations (9), (12) and (17). It shows the optimum distribution of mass between p and f, their sum being constant and $K_2 = 0$, as a function of $p + f$ for (*a*) maximum V_c^2/t_b with constant A; (*b*) maximum V_c^2/t_b with constant V_e; and (*c*) minimum t_0 with continuous thrust and constant

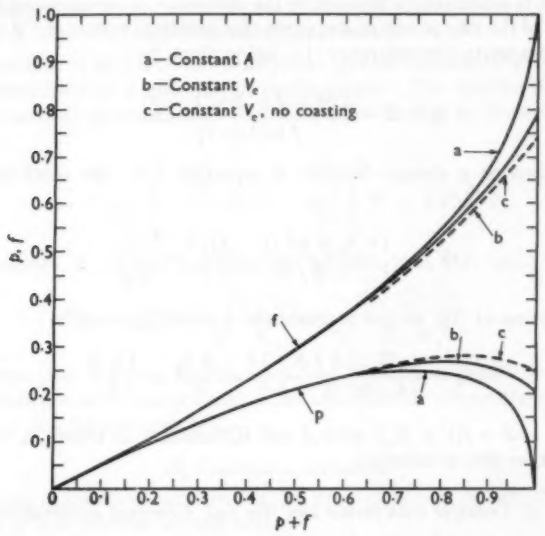

FIG. 1. The optimum mass distribution between propellent and power plant in an ion rocket for three sets of design restrictions: (*a*) maximum V_e^2/t_b with constant acceleration, (*b*) maximum V_e^2/t_b with constant exhaust velocity, (*c*) minimum transfer time with continuous thrust and constant exhaust velocity

V_e. It can be seen that these curves differ substantially only for values of $f + p > 0{\cdot}7$ and that for values of $f + p < 0{\cdot}4$, *i.e.*, when the mass of the rocket varies only slightly during the journey, f and p are approximately equal.

(*b*) *Transfer with thrust and free fall: Constant exhaust velocity*

If we remove the uneconomic requirement of continuous thrust, t_0 is minimised if there is a coasting period between the two power manoeuvres and we have the relation:

$$t_0 = t_1 + (S_0 - S_b)\frac{2}{V_e} + t_2$$

Since S_b is given by equation (16A) this can be rewritten:

$$t_0 = \frac{2\,S_0}{V_e} + t_b + \frac{2\,t_b\,(2 - f - 2\sqrt{1-f})}{f \ln (1-f)}$$

Using equation (7B) we now have:

$$t_0 = \frac{2\,S_0}{V_e} + \frac{t_b\,\phi}{2} = \frac{2S_0}{V_e} + \frac{f\,K_1\,V_e^2\,\phi}{4p \ln^2(1-f)} \quad \ldots \quad \ldots \quad (18)$$

where $\phi - 1$ is essentially a measure of the difference in curvature of the velocity time curves of the two power manoeuvres; for practical values of f, ϕ is negligibly different from unity [see reference (1)], being given by:

$$\phi = 2 + \frac{4\,(2 + f - 2\sqrt{1-f})}{f \ln(1-f)} \quad .. \quad .. \quad .. \quad (19)$$

If V_c is taken as a design variable in equation (18), the condition $\frac{dt_0}{dV_c} = 0$ gives us:

$$V_c = \left\{\frac{4\,S_0\,p\,\ln^2(1-f)}{\phi\,f\,K_1}\right\}^{\frac{1}{2}} = \frac{2\,S_0}{t_b\,\phi} \quad .. \quad .. \quad (20)$$

On substitution in (18) we get a minimum value of t_0 given by:

$$t_0 = \left\{\frac{27\,S_0^2\,\phi\,f\,K_1}{4\,p\,\ln^2(1-f)}\right\}^{\frac{1}{3}} = \frac{3\,S_0}{V_c} = \frac{3\,t_b\,\phi}{2} \quad .. \quad .. \quad (21)$$

For $p = 1 - d - f(1 + K_2)$, with d and K_2 constant as before, t_0 is minimised when equation (9B) is satisfied.

(c) Transfer with thrust and free fall: Constant acceleration

If the manoeuvre is carried out at a constant acceleration it is easy to see that the total distance traversed during thrust is given by:

$$S_b = \frac{A\,t_b^2}{4} = \frac{V_c\,t_b}{4}$$

Using equation (8) we can in this case replace equation (18) by:

$$t_0 = \frac{2\,S_0}{V_c} + \frac{t_b}{2} = \frac{2\,S_0}{V_c} + \frac{V_c^2\,K_1\,(1-f)}{4\,p\,f} \quad .. \quad .. \quad (22)$$

Equating $\frac{dt_0}{dV_c}$ to zero we find that t_0 is a minimum when:

$$V_c = \left\{\frac{4\,S_0\,p\,f}{K_1\,(1-f)}\right\}^{\frac{1}{2}} = \frac{2\,S_0}{t_b} \quad .. \quad .. \quad .. \quad (23)$$

and has the value:

$$t_0 = \left\{\frac{27\,S_0^2\,K_1\,(1-f)}{4\,p\,f}\right\}^{\frac{1}{3}} = \frac{3\,S_0}{V_c} = \frac{3\,t_b}{2} \quad .. \quad .. \quad (24)$$

The optimum mass distribution for constant d and K_2 is easily shown to be that given in equation (12).

It will be noticed from equations (21) and (24), that for constant exhaust velocity the period in free fall is a little more than half and for constant acceleration is exactly half the period under power.

Specific Impulses

(a) *Constant exhaust velocity*

Although it is of no particular utility, the specific impulse of a rocket has on occasion[3] been used as a criterion of performance. The specific impulse is in this case defined as the time integral of the thrust divided by the initial mass of the rocket:

$$I_{0a} = \frac{1}{M_0}\int_0^{t_b} -V_e \dot{M}\, dt = \frac{1}{M_0}\int_0^{t_b} \sqrt{-2P\dot{M}}\, dt \qquad .. \quad (25)$$

and for constant V_e it can immediately be seen that this has the value of

$$I_{0a} = V_e f = \sqrt{\frac{2t_b p f}{K_1}} = \sqrt{\frac{2t_b M_p M_f}{K_1 M_0^2}} \qquad .. \quad .. \quad (26)$$

It can be seen that this goes to infinity if t_b or M_f equals infinity, while for our standard condition of constant d and K_2 we immediately obtain the requirement of $p = f(1 + K_2)$ for maximum I_{0a}.

(b) *Constant acceleration*

In the case of constant acceleration, by using equation (8) and the relations from which it was derived we can write:

$$I_{0a} = \frac{\sqrt{2P}}{M_0}\int_0^{t_b} \sqrt{1-\dot{M}}\, dt = \frac{A}{M_0}\int_0^{t_b} M\, dt = \frac{A}{M_0}\int_0^{t_b} \frac{dt}{\frac{A^2 t}{2P} + \frac{1}{M_0}}$$

$$= \frac{2P}{M_0 A}\ln\left(\frac{A^2 t_b M_0}{2P} + 1\right) = \frac{2P}{A M_0}\ln\left(\frac{M_f}{M_0 - M_f}\right)$$

$$= -\frac{2p\ln(1-f)}{K_1 A} = -\sqrt{\frac{2p t_b(1-f)}{K_1 f}}\ln(1-f) \qquad .. \quad .. \quad (27)$$

For constant d and K_2 this is a maximum when $p = -(1-f)(1+K_2)\ln(1-f)$.

REFERENCES

(1) H. Preston-Thomas, *J.B.I.S.*, 1958, **16**, 508. (*See Errata below*).
(2) H. Preston-Thomas, "Realities of Space Travel," edited by L. J. Carter, p. 174, **1957**: London (Putnam).
(3) R. W. Bussard, *J.B.I.S.*, 1956, **15**, 297.

ERRATA

A Note on "A Nuclear Electric Propulsion System"

The following corrections should be made to the previous paper by Dr. H. Preston-Thomas (*J.B.I.S.*, 1958, **16**, 508):

Page 509, Eq. (3). *For* $I_{max} = f\sqrt{2t_b(1+K_2)K_1}$, *read* $I_{max} = f\sqrt{2t_b(1+K_2)/K_1}$.
Page 510, line 2. *For* V_e, *read* $\dot{V}_e$.
Page 516, Table I, column 3, line 4. *For* 0·3773, read 0·3764.

CORRESPONDENCE

(In these letters to the Editor, some passages have necessarily been omitted)

The Satellite Telescope

SIR,

May I, as an earthbound astronomer, comment upon the stimulating paper, "The Satellite Telescope."[1]

A Cassegrain reflector is a sound choice of telescope, but I am doubtful whether the resolving power attainable in practice with a segmented primary mirror is much superior to that of an individual segment. The segments could scarcely be figured together as a single optical surface unless they were positioned relative to one another with all the rigidity associated with the customary thick glass slab, and this would not be obtained with a light alloy lattice. On the other hand, it would be quite feasible to figure each segment separately as an off-axis paraboloid, and subsequently to adjust their relative positions in orbit, where a light alloy lattice would furnish adequate stiffness; in this case the segments would be replaceable in the event of major damage by meteors.

Meteor hazards have, I think, been overestimated. No ordinary meteor would break a piece of glass several inches thick: a small surface chip is a more probable contingency. This, of course, would not be detrimental to the image except in so far as it contributed to the scattered light which would limit the useful length of photographic exposures; when the mirror was realuminized the larger surface defects could be painted black to minimize such stray illumination. The life of the mirror might be limited by micrometeorite pitting, but I do not think we can yet tell definitely whether this is so. Incidentally, realuminizing should present little difficulty in space, with an ample vacuum chamber laid on, so to speak.

I feel that the author of the paper, Mr. F. A. Smith, has not regarded the difficulties arising from temperature variations and thermal gradients within the telescope structure sufficiently seriously. It is very noticeable when one is working with a large telescope, how rapidly the focus changes with temperature as the length of the supporting structures of the Cassegrain secondary changes. In Mr. Smith's design, these structures run straight to the edges of the secondary, and form with that mirror an optical lever which is extremely sensitive to temperature: a difference of 1° C. between opposite supports will cause a deflection of about three minutes of arc, moving the image on the photographic film by nearly a centimetre. Of course such gross sensitivity to temperature is quite intolerable. It could be reduced by a factor of five simply by supporting the secondary on cross-pieces which were attached to the principal supporting structures just inside the outer shell, rather than at the edge of the secondary mirror itself. In addition, it would seem wise to shield the instrument from direct sunlight, perhaps by an opaque screen a kilometre or so from the telescope. The only complete answer to the problem may, however, lie in Invar steel—not a pleasant prospect from the point of view of weight.

Although the author supposed that a photographic film is unlikely to

perform well near absolute zero, he apparently forgets that the same considerations apply to the observer. The temperature, however, of any body in radiative equilibrium with the Sun and the same distance from it as the Earth is likely to be reasonably comfortable; and if the Sun is allowed to shine unrestrictedly upon the observatory then probably neither film nor observer will be seriously perturbed. If, on the other hand, the observatory is shielded from sunlight it will come approximately to radiative equilibrium with the Earth. The temperature in this case will be low and dependent upon altitude. It will be as well, therefore to choose a nearly circular orbit for the instrument, and some means of warming the observer but not the telescope may be essential.

A great embarrassment is provided by the presence of an animate observer who is mechanically coupled to the telescope. The lateral moment of inertia of the projected instrument is 330 ton-ft.[2] Now, the astronomer weighs about 0·08 ton and has a radius of gyration of about 10 ft., and thus has a moment of inertia of 8 ton-ft.[2] He has only to move sideways one inch on his chair to displace the telescope about 50 seconds of arc. It is clear that any efforts made to achieve the theoretical resolving power of a 100-inch telescope—about $\frac{1}{20}$ second—with a segmented or any other mirror will be wasted if displacements a thousand times as great are occasioned by a movement of one inch on the part of the observer. Evidently an observer's presence raises considerable problems unless indeed the moment of inertia of the instrument is several orders of magnitude greater than is here envisaged. We must either dispense with the observer or house him in a cabin entirely independent of the telescope: the latter might be feasible although difficult.

In short, it appears that the telescope presently proposed would be quite unsatisfactory, and that drastic design changes are necessary before the building of the space telescope is contemplated. One notices in Mr. Smith's article a number of minor errors which do not change the sense, *e.g.*, "prime focus" for "Cassegrain focus," and "conjunction" of Mars, at the top of p. 364; but at least the article represents a start towards elucidating the problems of design and operation of the satellite telescope, and has been worked out in sufficient detail to make constructive criticism worthwhile.

Yours sincerely,

The Observatories, University of Cambridge, ROGER GRIFFIN.
Madingley Road, Cambridge.
14 *May*.

REFERENCE

(1) F. A. Smith, *J.B.I.S.*, 1958, **16**, 361.

Use of Collision Radar for Meteorite Avoidance

SIR,

Assuming, with Castruccio,[1] that a maximum range radar can detect meteorites within a distance of 100 miles of a space vehicle we can calculate the chance that a detected meteorite will turn out to be on a collision course. This chance will be simply a/A where a is the average cross-sectional area of the space vehicle viewed from all angles, and A is the area of a circle of 100 miles radius. If we take $a = 400$ ft.^{2}, $a/A = 5 \times 10^{-10}$.

Now the radar must be omnidirectional and must detect all objects entering sphere of sensitivity. The average length of time a given meteor stays within range will be about 3 seconds. Assuming that only one meteorite can be dealt with at a time the maximum handling rate for, say, 90 per cent. efficiency will be about two a minute (as the meteorites occur at random times, a rate of two a minute will still permit 10 per cent. of all arrivals to occur while the radar is still occupied with a previous one). Consequently, the maximum possible rate of useful detections (detections of meteorites on collision courses) will be $2 \times 5 \times 10^{-10}$ per minute. This is a rate of one meteor collision avoided every 1,900 years!

If the radar range is increased the problem of dealing with the numerous near misses becomes more intractable. If the range is reduced the time permitted for avoidance becomes uncomfortably small. It would seem that some new principle is needed if radar is to be useful in avoiding cosmic debris.

Incidentally, it would be very reassuring to have protection from meteorites of mass less than one pound—or less than one ounce for that matter.

Yours sincerely,

4881 West Saanich Road, Royal Oak, British Columbia, Canada.

P. E. ARGYLE.

REFERENCE

(1) P. A. Castruccio, *Aviation Week*, September 3, 1956, **65**, (10), 82; quoted by E. T. B. Smith, *J.B.I.S.*, 1957, **16**, 47.

Electrical Theory of Gravity

SIR,

In his recent letter[1], Dr. Ba Hli outlines an interesting theory on the nature of gravitation. We would like to point out a difficulty however, which seems to undermine the theory.

Coulomb's law for the electrostatic force between two charged bodies is correctly quoted for the case where the bodies are separated by vacuum. Where there is an intervening dielectric medium however, the formula should read

$$F_e = \frac{e_1 e_2}{k r^2}$$

where e_1 and e_2 are the electric charges of the bodies, r is the distance between the bodies and k is the dielectric constant of the intervening medium ($k = 1$ for vacuum). This means that if a sheet of material of high dielectric constant (such as water) is inserted between the Earth and a given body, then the weight of the body should show a *reduction* compared with its weight with a vacuum intervening. Experiment does not reveal this behaviour (as did H. G. Well's fictitious "Cavorite") and Dr. Ba Hli himself points this out.

The attraction of the material medium itself cannot be invoked here to make up the "lost" weight for the following reason. The dielectric constant varies with temperature (for example $k = 88$ for water at 0° C. and $k = 48$ for water

at 100° C.)[2], but temperature will not in general vary the number of charge pairs in the medium and therefore would not vary the net electrostatic force.

Yours faithfully,

The English Electric Company Ltd.,
The Airport, Luton, Bedfordshire.
5 *November*.

D. J. CASHMORE,
C. N. GORDON.

REFERENCES

(1) F. Ba Hli, *J.B.I.S.*, 1958, **16**, 540.
(2) "Handbook of Chemistry and Physics," 35th edn., p. 2325. **1953**: Cleveland, Ohio (Chemical Rubber Publishing Co.).

The Nuclear-Powered Ion Rocket

SIR,

In a recent paper[1], dealing with criteria for the optimum operation of a nuclear-powered ion rocket, the equation for the characteristic speed of such a rocket travelling with constant acceleration and constant power output was given [Eq. (14)] as:*

$$V_c = \sqrt{\frac{2pt_b}{K_1} \frac{f}{1-f}}.$$

From this equation the optimum (resulting in maximum $V_c^2 K_1/t_b$) distribution of mass between working fluid and power plant for a predetermined value of $f + p$ [it seems $p + f(1 + K_2)$ was meant] was derived [Eq. (15)] as:

$$p = f(1-f)(1+K_2).$$

No account was taken of the fact that the available energy of a nuclear rocket, although no doubt large, is limited. Thus, if the available energy per unit initial rocket mass

$$e_0 = \frac{p}{K_1} t_b$$

is prescribed, then:

$$V_c = \sqrt{2e_0 \frac{f}{1-f}},$$

and

$$\frac{dV}{dt} = \frac{V_c}{t_b} = \sqrt{\frac{2}{e_0 K_1^2} \cdot \frac{f}{1-f} \cdot p^2}.$$

From these equations it follows that:

(*a*) V_c increases with increasing f; there is no optimum distribution between f and p.

(*b*) The acceleration is maximum when

$$p = 2f(1-f)(1+K_2),$$

which is just twice the value previously[1] deduced.

Sincerely yours,

Department of Engineering,
University of California,
Berkeley, California, U.S.A.

G. LEITMANN.

REFERENCE

(1) H. Preston-Thomas, *J.B.I.S.*, 1958, **16**, 508.

* The nomenclature is that of the reference paper.

THIRTEENTH ANNUAL GENERAL MEETING

The Thirteenth Annual General Meeting of the British Interplanetary Society was held in the Kent Room, Caxton Hall, London, S.W.1, on Saturday, 19 July, 1958.

Present:

K. W. Gatland (*Vice-Chairman of Council*) in the Chair
L. J. Carter (*Secretary*)

and about twenty-five other members of the Society.

The SECRETARY read the notice convening the meeting, which had been printed in the May-June, 1958, issue of the *Journal*.

Chairman's Address

Mr. K. W. GATLAND (Vice-Chairman) announced that he was taking the Chair in the absence abroad of the Chairman of Council, Dr. L. R. Shepherd. He declared the meeting open and suggested that the Chairman's Address be taken as read, as it had already been printed on pp. 429-435 of the May-June *Journal*. Mr. Gatland continued by drawing attention to the great changes which had taken place in the field of astronautics during the past year. This now placed upon the Society an increasing responsibility, and in keeping with the new standards now expected in astronautics it was necessary for us to expand our activities, particularly as regards publications. The *Journal* would appear in a larger format as from 1959, and it was hoped that this would attract more advertising.

Annual Statement of Accounts and Balance Sheet

Mr. L. J. CARTER (Secretary) presented the statement of accounts and balance sheet for the period 1 October, 1956, to 31 December, 1957, which had been circulated with the May-June *Journal*. He mentioned that the Council had become increasingly preoccupied with financial matters over the past year, as the inflationary trends, particularly in postage and stationery, coupled with the fact that we were now issuing more material, had placed a burden on the Society which considerably exceeded the recent increase in fees. He mentioned that the necessity of obtaining funds from other sources would become increasingly essential during the coming years and that the Society would need all the financial help from its members which it could obtain.

It was then proposed by the CHAIRMAN that the audited accounts for the period to 31 December, 1957, be approved and, after seconding by G. V. E. THOMPSON (Fellow), the matter was put to the meeting and unanimously approved.

Election of Members of Council

The report of the scrutineers (Mr. G. Savage and Mr. P. R. Freshwater) on the election of four Members of Council was read, and the following were declared elected:

1. K. W. Gatland. 2. G. V. E. Thompson. 3. P. Moore. 4. G. S. Brosan.

The CHAIRMAN said the ballot papers had contained an error. There were five vacancies on the Council, as indicated in the Agenda, but on the ballot form members had only been asked to vote for four candidates. He moved that the fifth vacancy should be filled by the candidate with the next highest number of votes. This was seconded by Mr. D. S. CARTON (Fellow) and carried *nem. con.* It was then announced that

5. Dr. N. H. Langton.

had also been elected.

The CHAIRMAN said that he was particularly glad to welcome a new Member of Council, Dr. G. S. Brosan. He proposed a vote of thanks to the unsuccessful candidates (Dr. W. R. Maxwell and Mr. J. Foley) for their interest and enthusiasm in the Society in standing for election. This was seconded by Mr. E. HOPE-JONES (Fellow) and carried unanimously.

Size of the Council

The CHAIRMAN then drew attention to the proposal that power should be given for the number of Members of the Council to be increased from 12 to 15, and pointed out that, at the present time, the Council constituted a working group of the Society and it was quite impossible for them to carry out their duties without additional help. However, this was not to say that the purpose of the increase was merely to advance the number of people who would undertake day-to-day work for the Society, but rather to make it possible for an approach to be made to Fellows of distinction whose association with the Council would prove of benefit in other ways. He formally proposed the adoption of the resolution:

"That the total number of the Members of the Council be increased from 12 to 15."

This was seconded by Mr. E. HOPE-JONES (Fellow), and on being put to the meeting was carried *nem. con.*

Notice of Nomination for Election to the Council

The Secretary introduced the Special Resolution that Article 16 be altered by requiring that Notice of Nomination to the Council be extended from 6 to 12 weeks. He said that this was a very desirable thing to be put into effect, because it would thereby provide adequate time for overseas members of the Society to cast their vote. Normally, the regulations of bodies such as our own did not provide for such an extended period but the effect of this was that, effectively, all elections were made by a more-or-less resident group. This was the one thing which we were anxious to avoid, for the Society had always been international in its outlook and approach to every problem, and this demanded that every member of the Society should have an equal part to play in its activities.

He thereupon formally proposed the motion:

"That Article 16 be amended by the deletion of the word "six" and the insertion of the word "twelve" in its place."

After being seconded by DR. N. H. LANGTON, the Resolution was put to the meeting and unanimously agreed.

General Discussion of the Affairs of the Society

The Chairman said that he hoped that members would now raise any points concerning the Society.

Mr. D. S. CARTON (Fellow) said:

"There are a number of remarks that I should like to make, mainly upon the broad policy of our Council. Some of these will be to underline and add a further note of urgency to statements already made by the Chairman in his address. I also have one or two points of criticism to make, and also some suggestions.

"To start with I wish to draw the attention of members to the growing activities of older established societies both in this country and elsewhere, in some of the fields which we have looked upon as our own prerogative up until now. At present, with one or two exceptions, these activities are only on a small scale. But I think it is fairly certain that the activities of these societies will continue to grow as the interest of their specialist members is aroused in particular aspects within the broad field of astronautics. And as their activities grow, they are going to set this Society some very difficult problems, for it must be borne in mind that these societies have large and often elite memberships, large budgets, excellent publication facilities, and very adequate administrative organizations, compared with our own. In addition, this activity is occurring on an international as well as a national level. This year, as well as our own International Astronautical Federation Congress in Holland, there is a meeting being held in Madrid of the First International Congress of Aeronautical Sciences, which is including astronautics amongst its papers. The point to which I wish to draw special attention is that whilst it is a good thing to have more and more people interested in various aspects of astronautics, there are serious problems that must be appreciated regarding the attitude of other societies. In the first case practically all of them have their main interests outside astronautics, and secondly, practically all of them exclude from membership those without adequate scientific or engineering qualifications and experience. In fact, were our own Society to cease operation for any reason, a large number of our members would be excluded from many of the activities they now enjoy, and perhaps even more important, the field of astronautics as now covered by our Society would be scattered piecemeal amongst quite a number of specialist organizations without cohesion, and probably without much overall coherence.

"There is nevertheless some reason for hoping that, in spite of the growing outside interest, this Society will continue to grow in strength and notability provided it aims in the right direction. I think that the main outside interest will come from the aeronautical societies, but that their central subject in this matter will be that of guided weapons and, to a lesser extent, the reporting of work already undertaken in the field of satellites and space vehicles as this information becomes unclassified and available. It is within these limits that the main outside interests will be centred. It is here that our own Society should be prepared to give ground to some extent, leaving us free to continue to look ahead, to think and talk about the problems that still have to be faced in the immediate and more distant future.

"In concluding this part of my remarks, I want to underline again the urgent need for this Society to continue its activities (at all technical levels, in lectures and in publications, and in maintaining its appeal to specialist and non-specialist, member and non-member) in the broad span of spaceflight and astronautics, looking as often as possible to the problems of the future, and at the same time being prepared for ever increasing activity on the part of other organizations with more limited, specialist interests within the same field.

"Turning now to the publications of the Society, and bearing in mind my previous remarks, it appears most important that our publications should, wherever possible, make self-evident the scope of the interests of the B.I.S.

"Turning for a moment specifically to the *Journal*, this has a most difficult task to perform. It must maintain a reasonably high technical level of content, and over a period must cover as wide a range of interest as possible. To see how successful it has been in this, I analysed the contents of the last six *Journals*.

"My immediate reaction was that medicine, such a wide and important aspect, did not appear to be doing very well at the moment, and I note that there are no papers accepted for publication on this subject either. It is also my own personal opinion that we may be slightly overdoing orbits, but that the balance may come out over a longer period. Vehicle optimization is also getting the position its importance deserves. On the other hand, I am very doubtful about the weight being given to Satellite Tracking, namely one paper

(30 pages long) which is a reprint from an American Vanguard, Minitrack Report. I am concerned that so much space should be given to a paper already available, in English, to those that require it.

"Arising from this is the fact that there appears at present to be a trend towards the publication of longer papers. In the last three *Journals* each has contained a paper of 25 pages or more, and in two cases these papers are the only ones presented. I feel quite strongly that this is not a good idea. In fulfilling the two basic requirements, of quality of content, and wide coverage over a period of time, two other points must be carefully borne in mind. First, that each *Journal* must be considered as an advertisement for the Society, and that with the currency of each issue, several people of various technical abilities and specialisation must decide to join, or not to join, with little more evidence than a single copy. The second point is that I feel that there must be a group amongst the membership, each with rather limited specialist interests, who are members purely with the intention of obtaining information within a certain field that interests them. The present trend is failing to meet these two important aspects. As an alternative to this trend, I would suggest either that long papers be published in two parts, and that the papers published with them be of considerably different interests, or that long papers are only published in *Journals* where the rest of the "standard items" are short, so that other papers may also be included. I suggest that the number of times that this happens in a year is limited to say, two issues. In the analysis of the contents of the last six *Journals*, a further point emerges: the TECHNICAL REVIEW runs to 51 pages. This is undoubtedly a marathon effort on the part of E. T. B. Smith, and I feel that he should be congratulated upon it. Nevertheless, there are some queries that I want to raise on the matter. First, should this review appear in the *Journal* or in *Spaceflight?* Second, is the form of the review, as at present, best suited to its aim? Finally, precisely who does it aim to inform about what? My own answers to these questions appears to be at variance with those of the Publications Committee, and I must admit to some bias on this matter, which is worthy of some serious consideration.

"There are two other points, the first having something of personal interest. At present, if a paper is accepted for publication in the *Journal*, it appears to be likely that a delay may occur of more than twelve months before it is printed. I feel that this is slightly too long and that the originality of work may be lost because it occurs. I also think that authors should be informed of the probable date of publication, or perhaps the latest date, in case they wish to send it for consideration elsewhere. The other point arises from this overloading. Does Council, or the *Journal* Publication Committee recommend papers to *Astronautica Acta?*

"Leaving the *Journal*, I should like to enquire once again about the *B.I.S. Handbook*. I feel that this has been threatening to put in an appearance for far too long.

"Passing quickly on to another matter, I would like to suggest that the Society either recommends an existing book, or else authorizes a book to be written in its name somewhat similar to the *Handbook*, but written at a level which would permit our ordinary membership to obtain a sound introduction and foundation to the wide field of astronautics. In spite of the large number of books already published, I am now convinced that there is still a gap to be filled at this point.

"At long last, I come to my concluding comments: the lecture programme of our Society and its Branches. In the first instance I have little criticism of their general content. They appear broadly to fill our technical needs. There are nevertheless two suggestions that I would like to make. The first is that it might be a good idea to designate certain lectures through the year as "Main Lectures" and that these should take place not only in London, but also at the Branches. The second suggestion that I put forward is the possibility of holding a number of one-day symposia, comprising six to eight review papers and discussion intended to inform and interest our own membership and the public. And that they be held in London, the Branches, and prehaps elsewhere. Perhaps one paper could as it were be a B.I.S. Booster."

In reply, the SECRETARY said that it was probably true that a fair proportion of published material was concerned with reporting work which had been undertaken and this was a necessary function of the Society, though his own view agreed with Mr. Carton's in that we should much more actively pursue forward-looking activities. The idea of one-day Symposia was well worth adopting and would be reported to the Council for further consideration.

In regard to competition from older bodies, this is a matter which we take seriously to heart.

Mr. G. V. E. THOMPSON (Editor of the *Journal*) then dealt with some of the points raised by Mr. Carton concerning *Journal* publications policy. The Editor and other members of the Publications Committee were continually seeking to improve the standard of the *Journal*. As regards covering a wide range of interest and maintaining balance, we, of course, did not purposely exclude any branch of astronautics. While it was possible to attempt to rectify deficiencies by trying to commission articles in particular fields, ultimately one depended upon what authors were prepared to supply. To hold up otherwise satisfactory papers because there had been a glut on that topic was only increasing the delay which Mr. Carton also complained about.

Regarding the specific paper which Mr. Carton mentioned—the Minitrack report—the Publications Committee had been in two minds as to whether it should be printed. It was not readily available in this country but at the time it looked as if it might be of interest to many who wished to undertake satellite tracking. As it happened, a large number of enquiries were received, from both members and non-members, for the preprint of the paper which was made available.

While the Publications Committee were anxious that authors should express themselves as concisely as possible, it would hardly be proper for the length of a paper to be one of the main considerations in deciding whether to accept it or not. It might on occasion be necessary to publish long papers in two or more parts, but there were several reasons why this should not be done unless absolutely necessary.

The real answer to most of Mr. Carton's points, including that concerning delays in publication, was that the *Journal* was not large enough. There was sufficient material available to publish a larger monthly periodical, but this was not possible on our present income. As Mr. Carter had already pointed out, we needed other sources of funds.

We did not recommend papers to *Astronautica Acta*; it was open to any person to send in contributions and there was an Editorial Board to assist in selecting the papers for publication.

Mr. E. HOPE-JONES submitted a plea that the voting procedure be altered and that, instead of the present system, the arrangements should be voting on the basis of proportional representation by a single transferable vote. He pointed out that this had been adopted elsewhere (*e.g.*, in Eire) and that it represented the most democratic way of selecting Members of the Council.

The SECRETARY replied that he felt that the democratic system of this country and elsewhere was quite good enough for the Society to adopt, and that, really, the idea of the transferable vote was a political manoeuvre of particular importance to a minority party. In any case, the cost of preparing Special Resolutions and explanatory slips and advising the members and requesting their vote, besides the large volume of work which would undoubtedly arise from members who would want to comment on the matter, would probably

amount to about £200, and this was obviously money which we could ill-afford at present and which we could put to better use elsewhere.

After further discussion by the members present, one of whom pointed out that the system had been adopted at his University and gave exactly the same result as the present system, the meeting closed without putting the matter to vote. Mr. Hope-Jones indicated that he would give the matter further consideration with the view to raising it at a later A.G.M.

In conclusion, the CHAIRMAN thanked all of those who had attended a meeting which had lasted for a very long time and announced that plans for holding a 1959 I.A.F. Congress in Moscow had not been adopted, on the grounds that insufficient time was available for organizing it. In accordance with existing plans, it therefore fell to the B.I.S. to undertake this task. The organization of such a large and important Congress at such very short notice was obviously going to be a matter which would throw an immense strain upon the Society's resources, and he hoped that any members who would be willing to provide unstinted help would communicate with the Secretary.

There being no other business, the Annual General Meeting was ended.

B.I.S. NEWS

Income Tax Relief for Annual Subscriptions

The Society has been approved by the Commissioners of Inland Revenue for the purposes of Section 16 of the Finance Act, 1958, and members who qualify for relief under that Section will, in future, be able to claim the whole of their annual subscription as a deduction from their emoluments assessable to income tax under Schedule E. In order to qualify for relief a member must be able to show that:

(*a*) the subscription is defrayed out of the emoluments of his office or employment, *and*,

(*b*) the activities of the Society so far as they are directed to all or any of the following objects:

(*i*) the advancement or spreading of knowledge (whether generally or among persons belonging to the same or similar professions or occupying the same or similar positions);

(*ii*) the maintenance or improvement of standards of conduct and competence among the members of the profession;

are relevant to the office or employment, that is to say, the performance of the duties of the office or employment is directly affected by the knowledge concerned or involves the exercise of the profession.

The first subscription for which relief may be claimed is that payable on 1 January, 1959. Members who are eligible for relief should apply to their tax offices as soon as possible for form P358 on which to make a claim for adjustment of their P.A.Y.E. coding. It is understood that members will **not** be required to produce a receipt for the payment of the subscription.

Publications: Binding Arrangements

This issue completes Volume 16 of the *Journal*, and includes the index and title page. Members who wish to have the volume bound should send the ten issues for 1957–58 direct to W. Heffer & Sons Ltd., Hills Road, Cambridge, together with a remittance of 11s. 0d. per volume (charge for United Kingdom residents). Please do not send them to the Society. Earlier volumes of the *Journal* can be bound at a similar cost.

The September issue of *Spaceflight* completed Volume 1 and contained the index and title page. The cost of binding this publication (nine issues) is 18s. 6d., and here again copies should be sent with remittance to Messrs. W. Heffer & Sons Ltd., Hills Road, Cambridge.

Volume 17 of the *Journal* and Volume 2 of *Spaceflight* will each run until the end of 1960; as has already been announced, the page size of the *Journal* will in future be the same as that of *Spaceflight*.

Election of Members

The following elections were made at the Council Meeting on 3 May, 1958:

Fellows.

David Belcher, B.Sc., 29, Winnock Road, Yiewsley, Middlesex.
Derek William Fallows, Officers' Mess, R.A.F. Titchfield, Nr. Fareham, Hampshire.
Malcolm John Prosser, P.O. Box 60, Kitwe, Northern Rhodesia.
Coleman Raphael, M.E., 2, Scott Place, Glen Cove, New York, U.S.A.
Johannes Frederick Uys, B.Sc., Dept. of Electrical Engineering, University of Stellenbosch, Stellenbosch, South Africa.

Senior Members.

James Rankin Reid Burton, 8, Hamilton Drive, Glasgow, W.2.

Members.

Robert Blakemore, 13, Gregory Avenue, Breightmet, Bolton, Lancashire.
Donald George Brown, B.Sc., 9134–45th Avenue, S.W., Seattle, 16, Washington, U.S.A.
Douglas Greere Carroll, c/o P.A.A. Hotel Metropole, Karachi, Pakistan.
William Roger Corliss, M.S., 2068, Snowhill Drive, Cincinnati 37, Ohio, U.S.A.
Henry Holway, 35, Lupus Street, London, S.W.1.
Peter Robert Innocent, 21, Anthony Crescent, Alvaston, Derby.
William Simister, 20, Bridge Street, Haverfordwest, Pembrokeshire.
Stanley Eric Simmonds, 37, Willow Way, Hatfield, Hertfordshire.

The following elections were made at the Council Meeting on 7 June, 1958:

Fellows.

David Albin Anderton, B.Ae.E., 11, rue Michel Chauvet, Apt. 1135, Geneve, Switzerland.
Francis Rodwell Banks, C.B., O.B.E., 5a, Albert Court, London, S.W.7.
Derek Arthur Bean, 41, Wimbledon Park Road, Southfields, London, S.W.18.
John William Burley, 12, Neithrop Avenue, Banbury, Oxfordshire.
John William Converse, B.Sc., 21111, Lassen Street, Chatsworth, Calif., U.S.A.
Thomas Alan L. Davies, B.Sc., 61, Mill Park Drive, Eastham, Wirral, Cheshire.
Ragnars Martins A. Eggerts, B.Sc., House No. 10, F.C. College, Lahore, Pakistan.
Gordon Walter C. Garrould, M.I.Mech.E., No. 2, Harrington Road, Chetput, Madras-31, India.
Maurice Edward Goldstein, B.Sc., 75, Grosvenor Road, Lindfield, N.S.W., Australia.
Ake Lennart Haborg, Sandhamnsgatan 19, Stockholm, Sweden.
Daniel Tuttle Hedden, B.A., M.Sc., 324, Dug Road, South Glastonbury, Connecticut, U.S.A.

GEORGE LAWRENCE JOHNSTON, B.S., 3915, Ocean Drive, Manhattan Beach, Calif., U.S.A.
GEORGE TALBOT KELTON, B.S., 2061, Valley View, Norco, Calif., U.S.A.
ALBERT MEREDITH MORGAN-VOYCE, B.Sc., 6021b, Karen Circle, Fort Worth 16, Texas, U.S.A.
JOSEPH OSTWALD, B.Sc., 80, Swinburne Street, Lutwyche N3, Brisbane, Queensland, Australia.
SHAD MD. FAZLUR RAHMAN, M.Sc., Dept. of Physics, University of Dacca, Ramma, Dacca (East Pakistan).
HERBERT REISMAN, M.Sc., 6129, Fairfield Drive, Littleton, Colorado, U.S.A.
DONALD ROBERT RHODES, B.E.E., M.Sc., Ph.D., 1510, Mizell Avenue, Winter Park, Florida, U.S.A.

Senior Members.

DERRICK COOPER, 76, The Larches, Palmer's Green, London, N.13.
RICHARD TOM H. ELLIS, 221, Romford Road, London, E.7.
PATRICK THOMAS ENGLISH, 1729, Bolton Street, Baltimore 17, Maryland, U.S.A.
ARTHUR CONRAD FITZGERALD, c/o The EX-Lands Nigeria, Ltd., P.O. Barakin Ladi, Northern Nigeria, W. Africa.
MARTIN IRWIN WILLINSKI, 18542, Sunburst Street, Northridge, Calif, U.S.A.

Members.

HENRY WILLIAM ALLEN, 5, Arnold Road, Tottenham, London, N.15.
PAUL DAVID ARTHUR, M.S., Ph.D., 11221, Gloria Avenue, Granada Hills, Calif., U.S.A.
JOHN LANDES BARNES, M.A., M.S., Ph.D., 1007, Broxton Avenue, Los Angeles 24, Calif., U.S.A.
IAN CLARK, 219, Greenhead Street, Glasgow, S.E.
Lee HAFNER COMBS, 264, Tigertail Road, Los Angeles 49, Calif., U.S.A.
B. MARTIN DONABEDIAN, B.S., 5039, W. 62nd Street, Los Angeles 56, Calif., U.S.A.
NATHAN ESTERMAN, 18, Onslow Gardens, Muswell Hill, London, N.10.
RAYMOND VICTOR FISHER, 14, Wellsway, Keynsham, Somerset.
MAITLAND SIDNEY HARVEY, P.O. Box 6247, Nairobi, Kenya, East Africa.
GEORGE WILLIAM HOSANG, 25, Bonnington Place, Willowdale, Ontario, Canada.
ERIC ROY JACOBSON, 49, Troon Road, Greenside Ext., Johannesburg, South Africa.
ROBERT VICTOR KING, B.A., Christ Church Vicarage, 150, Kew Road, Richmond, Surrey.
PETER MACK, 315, S.W. 12th Street, Fort Lauderdale, Florida, U.S.A.
PETER DAVID MARSHALL, 8, Nethercott House, Devons Road, Bow, London, E.3.
ALBERT MICHAEL MICELI, B.A., 27, Sylla Avenue, Toronto (Scarboro), Ontario, Canada.
JESSE LAFAYETTE MITCHELL, B.S., 334, Darby Avenue, Hampton, Virginia, U.S.A.
CHARLES HUMPHREY MULLER, 36, Fort Street, Bloemfontein, South Africa.
MARY MUNRO, 6, Lynnwood Avenue, Newcastle 4, Northumberland.
CLAIR OMAR MUSSER, M.E., 12997, Blairwood Drive, Studio City, Calif., U.S.A.
EDWARD ARTHUR PARTRIDGE, 3, Stafford Grove, Toorak East, Marryatville, South Australia.
DAVID CHARLES PAYNE, 3, Windsor Road, Portchester, Hampshire.
STEPHEN CHARLES F. PIERSON, c/o Grindlays Bank Ltd., 54, Parliament Street, London, S.W.1.
JOHN OLIN SNEED, M.E., 768, N.W. 3rd Street, Miami, Florida, U.S.A.
PETER JOHN WATKINS, 159, Bishop Road, Bishopston, Bristol, 7.
ROBERT BRIAN YEADON, 5, Conolly Green, Redcliff, Southern Rhodesia.

The following elections were made at the Council Meeting on 19 July, 1958:

Fellows.

ELLWYN E. ANGLE, B.S., 501–19th Street, Santa Monica, Calif., U.S.A.
WILLIAM ERNEST M. ARCHER, A.M.Inst.B.E., Grad., I.E.D., 33, Dunella Road, Hillsborough, Sheffield, 6.
RICHARD WILLIAM BERG, B.S., 1721, Riverwood Lane, Box 214, Wisconsin Rapids, Wisconsin, U.S.A.
GORDON HOLT BYFORD, A.Inst.P., "Saas Fee," Upper Weybourne Lane, Farnham, Surrey.
REGINALD LEONARD CATER, A.F.R.Ae.S., c/o Westminster Bank Ltd., Bushey Green, Catford, London, S.E.16.

Frank Eaglesfield Chasemore, B.Sc., c/o M/s Liversey & Henderson, Oficina del Ingeniero Residente, Puerto de Acajutla, El Salvador, Central America.
Shih-Yuan Chen, M.S., Ph.D., 17, Sherman Avenue, Plainview, New York, U.S.A.
Michael Carey Clinch, 39, Abbey Road, Westbury on Trym, Bristol.
Clifford Herd Covington, B.A., 5830, 7th Avenue, Los Angeles 43, Calif., U.S.A.
Kenneth Hugh Fea, B.Sc., 4, Manor Drive, Hinchley Wood, Esher, Surrey.
Henry Charles King, M.Sc., Ph.D., 18, Sutton Avenue, Slough, Buckinghamshire.
Northam Lawrence, B.A., Royal Observatory, Hong Kong.
John Robert Milliron, B.Sc., 401, W. Xenia Drive, Fairborn, Ohio, U.S.A.
Robert Henry Merson, B.A., 46, Coleford Bridge Road, Mytchett, Nr. Aldershot, Hampshire.
Byron Wallace Soulsby, 21, Donhead Street, Elizabeth, South Australia.
Huseyin Cavit Topakoglu, D.Sc., SHAPE Air Defence Technical Centre, P.O. Box 172 The Hague, Netherlands.
Ian James Wilson, B.Sc., 12, Station Road, Swanage, Dorset.
Lynn Ellsworth Wolaver, B.Sc., 243, Pat Lane, Fairborn, Ohio, U.S.A.
Joseph Burdwood Woodford, 29, Tangham Walk, Basildon, Essex.
Sydney Wrightson, 7, The Limes, Ella Street, Hull, Yorkshire.

Senior Members.

John Thomas Brown, 47, Twybridge Way, Stonebridge Park, London, N.W.10.
Murray Horton, 66, Vancouver Drive, Winshill, Burton-on-Trent.

Members.

Frederick Henry Bellamy, 38, Allestree Lane, Allestree, Derby.
Leslie William Benington, c/o Merz & McLellan, P.O. Box 8229, Causeway, Salisbury, Southern Rhodesia.
Phiroze Dadyba Bilimoria, B.Sc., 5, Elphinstone Road, Poona 1, India.
Julian Charles Bowles, 51, Courtfield Rise, West Wickham, Kent.
David Alan Brymont, 35, Leigham Court Drive, Leigh-on-Sea, Essex.
Francisco Buch-de-Parada, Alpes 324, Lomas, Mexico D.F., Mexico.
Federico Rose Buenrostro, 4702, San Jacinto Street, Dallas 4, Texas, U.S.A.
Gerald Thomas Coan, 14, Gorsey Ln., Burtonwood, Warrington, Lancashire.
Felix Dominicus J. Dijkstra, Noord-Vliet 7, Leeuwarden, Netherlands.
Raymond Henry Ellis, 148, Kew Road, Richmond, Surrey.
Anthony James Farmer, 17, Argyll Gardens, Edgware, Middlesex.
John Daly Faust, B.A., Dept. of Physics, University of California, Berkeley, Calif., U.S.A.
Donald Sydney Fellows, 33, Blakeland Street, Small Heath, Birmingham, 9.
Scott Fletcher, B.S., 8711, Holme Drive, Philadelphia 36, Penna., U.S.A.
Michael John W. Gage, Pen-Tor, Park Corner, Penzance, Cornwall.
June Rose Garner, 43, Beverley Road, Luton, Bedfordshire.
George Wilfred Gash, 90, Meole Rise, Meole Brace, Shropshire.
Ernest William Goodwin, 24, River Close, Ruislip, Middlesex.
Peter William Haylett, Vancouver House, Kimberley Road, Bacton-on-Sea, Norwich, Norfolk.
Peter Howard, M.B.B.S., 135, Aldershot Road, Church Crookham, Hampshire.
Isac Jacobson, B.Sc., 58, Hakeshet Street, Ramat-Gan, Israel.
Vasily Vasil'evich Kibalko, 16, Kensington Palace Gardens, London, W.8.
John Macgregor, 11, Oxford Terrace, Edinburgh, 4.
Allen John Mackinnon, Folker Apts. 6, Oxford, Ohio, U.S.A.
Robert John Salkeld, A.B., M.B.A., 410½, Landfair Avenue, Westwood, Los Angeles 24, Calif., U.S.A.
George Shapiro, 3507, Jo Ann Drive, Baltimore 7, Maryland, U.S.A.
Robert Francis Sheehan, Partway House, RD 1, Old Oscaleta Road, Ridgefield, Connecticut, U.S.A.
Richard Theodore Smith, 403, S. 18th Street, Manhatten, Kansas, U.S.A.
Kate Wilhelm, 7410, Star Lane, Louisville 14, Kentucky, U.S.A.
Donald Ramsay Wonson, 163, Chetwynd Road, Guildford, N.S.W., Australia.

The following elections were made at the Council Meeting on 9 August, 1958:

Fellows.

John Cecil d'Arcy Benson, 4, Rambler Lane, Slough, Buckinghamshire.
Daniel Edgar Bloxson, B.A., 523, South Lucerne, Los Angeles 5, Calif., U.S.A.

James Quinn Brantley, B.E., Ph.D., 920, Greentree Drive, Winter Park, Florida, U.S.A.
John Edward Chacksfield, "Windover," Yew Tree Road, Dorking.
Seville Chapman, A.B., Ph.D., 2343, Kensington Avenue, Buffalo 26, N.Y., U.S.A.
Francis Robert C. Cimino, B.Sc., c/o Stone & Webster Engrg. Corpn., P.O. Box 488, Concrete, Washington, U.S.A.
Derrick William Draysey, 46, Skyrrold Road, Malvern, Worcestershire.
Albert Lee Halpert, B.M.E., B.I.E., 22, Puritan Path, P.O. Box 482, Port Jefferson, L.I., N.Y., U.S.A.
Hemraj Kothari, B.Sc., Grad.I.Mech.E., 19, Spencer Park, London, S.W.18.
Robert Berger Lynch, B.S., 10472, Joel Lane, Rancho Corova, Calif., U.S.A.
Marko Pivac, B.E., 408, S. Waverly Drive, Dallas, 8, Texas, U.S.A.
Thomas Sheridan, 256, Stockport Road, Ashton-under-Lyme, Manchester.
Maurice William Windsor, M.A., Ph.D., National Bureau of Standards, Free Radicals Research Section, Washington 25, D.C., U.S.A.

Senior Members.

Ronald Selwyn Garland, 3 RAR, C/GPO, Penang, Malaya.
Dennis George E. Garrard, 27, Blanchard Road, Dalston, London, E.8.

Members.

Angelo Bandettini, B.S., 143, Palmer Avenue, Mtn. View, Calif., U.S.A.
Timothy John Beal, 35, South Street, Hectorville, South Australia.
Richard Paul Brady, 2007, South Old Manor Road, Wichita, Kansas, U.S.A.
Herbert William Davidson, 23, The Turn, Loansdean, Morpeth, Northumberland.
Richard Francis De Faye, 5, Radipole Park Drive, Weymouth, Dorset.
Derek David Dempster, M.A., 73, Eccleston Square, London, S.W.1.
John Kenneth Densham, 74, Stuat Road, Waterloo, Liverpool, 22.
Peter David Dimmick, Naval School Training Ship, "Mercury," Hamble, Southampton, Hampshire.
Anthony Beresford Elphick, 12, Redford Avenue, Wallington, Surrey.
Terry Ralph Freund, 150, Williams Avenue, Kelso, Washington, U.S.A.
Jan Gadomski, D.Sc., Obserwatorium Astronomiczne, Al Ujazdowskie 4, Warzawa, Poland.
Peter Stephen G. Gooch, 1B, Salisbury Road, Southsea, Hampshire.
John William Grout, 61, Regine Road, London, N.4.
Raymond Michael Lawrence, 33, Frewer Avenue, Fairwater, Cardiff, Glam.
Kenneth Roberick McPherson, Fermain Ash Road, Hawley, Nr. Dartford, Kent.
Robert Garth W. McPherson, "Kinnaird," Warialda, N.S.W., Australia.
Tudor Anthony G. Randell, M.A., 612, Magothy River Road, Round Bay, Severna Park, Md., U.S.A.
Mario E. Rodriguez Ramirez, D.Sc., Observatorio Nacional, Casa Blanca, La Habana, Cuba.
David Ngan Soo, 13, Brynymor Road, Swansea, Glamorgan.
Ian Keith Spence, B.E., Students Hostel, High Street, Kensington, Sydney, Australia.
Michael W. Stapleton-Cotton, Cholstrey Lodge, Leominster, Hereford.
John Hilton Stowell, M.A., Box 670, Awali, Bahrain, Persian Gulf.
Eugene L. Ch. M. Strens, Burg De Manlaan 20, Breda, Holland.
Ivy Irene Woods, H.M.S. Dauntless, Burghfield, Reading.
David Gerard Wright, 25, Gillespie Crescent, Edinburgh 10

Deaths

The Council regrets to announce the deaths of:

Charles Antill Melhuish.
Marie Carmichael Stopes.
Brian Henry Tucker.

JOINT ACTIVITIES

Tenth International Astronautical Congress

Further information is now available concerning the Tenth International Astronautical Congress, which is being organized by the Society. It will be held in London during the week **31 August to 5 September, 1959,** and the main venue will be Church House, Westminster. This is a large building possessing several spacious halls, various committee rooms, a restaurant, and other amenities. It is situated in the administrative heart of the country, being but a few hundred yards from the Houses of Parliament, the principal Ministries, the Prime Minister's official residence (10 Downing Street), the Middlesex Guildhall, and County Hall. For a period during World War II when the Parliament buildings had been damaged during air raids, both Houses (Lords and Commons) held their meetings at Church House. It is undoubtedly the most suitable building in London that could be chosen for our purpose.

The Congress will be the most important international meeting on space research and astronautics to be held during 1959, and an attendance of several hundred is expected. Delegates from all the principal astronautical societies and organizations throughout the world will be present, and during the course of the Congress the business and committee meetings of the International Astronautical Federation will take place.

To most participants, the most important activity will be the papers read at the lecture sessions; preprints with translated summaries will be provided to all registering in good time. The papers will not be restricted to a single theme, but will cover a wide range of topics, including:

Research applications of satellites and space probes.
Existing and proposed projects for manned and unmanned space vehicles.
Results already obtained in space research.
Conventional and unconventional methods of propulsion in space.
Problems in dynamics, control and navigation.
Re-entry problems.
Biological and medical aspects of manned spaceflight.
Planetary astronomy
Legal problems.

It is intended that the Congress should be divided into Sessions according to the topics to be discussed, but the session headings will not be announced until the programme committee has a full list of titles of papers to be presented.

Prospective authors are invited to submit papers for presentation through the regional screening committees which are being set up by the Member-Societies of the I.A.F. Each author is asked to notify the Chairman of the appropriate regional screening committee of his intention to submit a paper, and should accompany this notification with a title and abstract (50-200 words) of the paper; these should be in triplicate (3 copies) and sent to reach the screening committee not later than 1 May, 1959. If the subject is approved, three copies of the manuscript should be sent in the same way by not later than 1 June, 1959. It is important that authors should adhere to these deadlines, to allow adequate time for preparation of preprints. Over 100

papers were presented at the last Congress, and it may prove necessary to restrict the numbers this time.

There will also be a lighter side to the week's activities. On the eve of the opening there will be an official reception at St. Ermyn's Hotel, Westminster, and a number of other evening receptions are being arranged—some of them sponsored by firms connected with the industry. Midway through the week, one day will be given over to an excursion to places of general interest. For those participants who do not wish to attend all the lecture sessions, visits to works and government establishments are being arranged. A ladies programme will include tours of historic London, visits to fashion establishments, etc. The week will conclude with a banquet at the Dorchester Hotel, Park Lane.

Although further announcements concerning the Congress will be made in both the *Journal* and *Spaceflight* from time to time, only limited space can be allocated for this purpose. The Congress Organizing Committee is therefore arranging to issue at fairly regular intervals a Congress Information Bulletin, which will contain detailed notices, instructions and news. These Bulletins will include particulars of the various national Screening Committees, the arrangements for travel and hotel accommodation, and eventually the programme and timetable. Anyone who is considering attending the Congress is urged to write immediately to **The Secretary, B.I.S., 12 Bessborough Gardens, London, S.W.1,** and ask to be placed on the Congress mailing list. Members are also asked to notify any of their friends or colleagues who might be interested; a small poster suitable for display in colleges and industrial organizations will also be available from the secretariat.

The organization of a conference of this size naturally entails a considerable amount of work and the Secretary would be glad to receive offers of assistance from members. During the next few months assistance will be needed in the preparation and dispatch of Congress Information Bulletins and other publicity; at the time of the Congress we shall need stewards, interpreters, couriers (to take charge of the organized visits), etc. It is intended to establish a committee of lady members and members' wives to organize the ladies' programme; those willing to assist in this work should write to the Secretary, who will also be glad to receive suggestions as to suitable visits or entertainments which might be provided.

Commonwealth Spaceflight Symposium

The I.A.F. Congress announced above will be preceded by a two-day symposium. The theme of this will be Commonwealth Co-operation in a Spaceflight Programme, and it will include communications from the British, South African, Canadian and Indian societies, contributions from B.I.S. members in other Commonwealth countries and a general discussion. Persons resident outside the Commonwealth will be allowed to attend as observers. The Symposium is to be held at Church House, Westminster, on Thursday and Friday, **27-28 August, 1959.** Further particulars will be announced in a later issue of the *Journal* and may also be obtained from the Secretariat.

REVIEWS

Project Satellite. Edited by Kenneth W. Gatland. 8½ × 5½ in. Pp. 169, illustrated. 1958. London: Allan Wingate. (21s.)

The editor's introduction defines the aims of the book. He shows how the development of present-day satellites has been a logical step following the use of high-altitude probe rockets. It is argued that the next phase is the construction of satellite space stations which will eventually lead to real space travel.

Henry J. White relates a tale by Wernher von Braun, recalling the early German rocket pioneers and their progress up to the end of the World War II. As much as I respect von Braun, this story of space-minded Peenemündians, who devised their brilliantly conceived and murderous vehicles because it was the only way to achieve space travel, is surely a romantic myth. Having had the good fortune to work alongside some ex-members of this team since the war, in this country, these men are better described as hard-headed, first-rate military scientists, with a job to do, quite impassionately. Incidentally, this chapter is almost word for word the same as an article published in the *Journal*, May–June, 1956.

The second chapter, contributed by the editor, is a concise and popular account of certain design studies which have led to the present Western satellites. It contains quite a lot of performance data on all the better known rocket vehicles, and discusses the Vanguard Project at length. Minitrack and Moonwatch are described in simple enough terms for the layman to appreciate. Honour is paid to Russian satellite achievements without adding any new information, while no American successes are reported since the book was published too hurriedly (?) to await von Braun's Explorer, or the first Vanguard. Is this lack of faith, or a desire to cash in on the subject's present topicality?

Orbital bases, the third chapter (by H. E. Ross), continues in the pseudo-scientific idiom which permeates the whole book. All the hazards of spacestation construction and occupation are re-stated. Likewise A. V. Cleaver's final chapter on interplanetary flight contains nothing which is new or unexpected.

Although it is technically very superficial and not entirely accurate, the newcomer to astronautics will find this well illustrated book an excellent first reader. To the old hand, and the genuine rocket engineer, it is just more hot air which we seem to have to suffer in order to popularize the subject.

How about our leading astronauts producing a real book which will convince the scientific professions of their depth of understanding of the engineering complexities of their subject?

K. C. GARNER.

Procedure for Obtaining Transient Response from Frequency Response, with Tables and Nomographs. By V. V. Solodovnikov, Yu. I. Topcheev and G. V. Krutikova. (Translated and edited by A. Gelbtuck, from ЧАСТОТНЫЙ МЕТОД ПОСТРОЕНИЯ ПЕРЕХОДНЫХ ПРОЦЕССОВ С ПРИЛОЖЕНИЕМ ТАБЛИЦ И НОМОГРАММ published by Spravochnoe Posobie Gosudarstvennoe Izdatel'stvo Tekhniko-Teoreticheskoi Literatury, Moscow, 1955). 9½ × 6½ in. Pp. v + 193, with 56 figures and 13 nomographs (in pocket). 1958. London: Infosearch Ltd. (42s.)

A method is described for computing the transient response of a servo from its frequency response by approximating the latter as a sum of trapezoids. The first part describes clearly the essence of the method, the second part consists of worked examples while the third contains tables of functions for evaluating the trapezoid integrals together with charts and nomographs of more general use in servo work. A knowledge of basic servo theory is assumed.

The style is simple and direct and appears to have lost nothing in translation, while the method itself is a useful tool for the servo designer, being particularly useful when the frequency response is not available in analytical form.

C. N. GORDON.